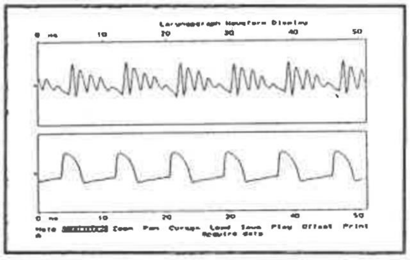
PCLX

A powerful combination

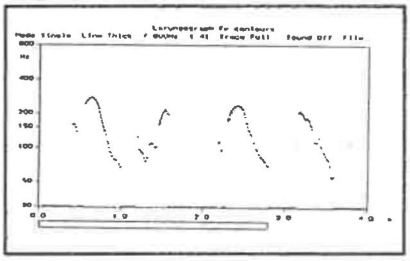
For Clinic, Laboratory and Classroom

Speech,
Electro-Laryngograph and
Pitch displays for
IBM^R PC compatibles

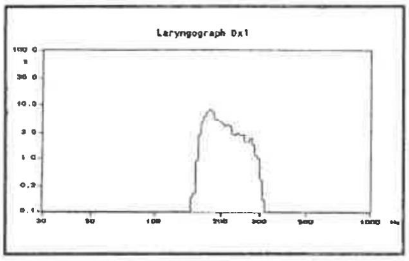
Real time speech and Laryngograph^R waveform (Lx) display

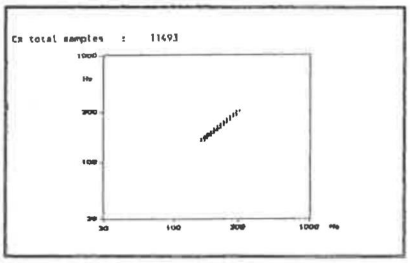

Laryngograph Waveform Display
0 ms
10
20
30
40
50
Zoom
Pan
Cursor
Load
Save
Play
Offset
Print
Acquire data

Microphone or electrode based pitch (fundamental frequency) displays


Laryngograph Fx contours
Mode Single
Line Thick
Trace Full
Sound Off
File
600
Hz
400
300
150
100
40
30
0.0
10
20
30
40

Many minutes of pitch analysis: distributions, cross plots and statistics.





- Monitor and analyse the vocal fold contact cycle for normal and abnormal voice
- Provide visual feedback for work with speech impaired and deaf speakers
- Train the professional voice
- Research speech and singing
- Teach intonation to foreign language students
- Effectively demonstrate and teach acoustic phonetics.
- Monitor gross laryngeal movements (e.g. swallowing) and relative vocal fold adduction

For more information contact:

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London NW1 2PE
Tel: London (71) 387 7793
Fax: London (71) 383 2039

The PCLX system:

1. Laryngograph Processor: a fully portable (or mains powered) electro-laryngograph and microphone pitch extractor.

2. PCLX interface card: Dual 16 bit, 64x oversampling A/D's (4 channel version also available), TMS320-25C processor, period timer, dual 16 bit d/a with tracking reconstruction filters, serial I/O port.

3. IBM^R PC/AT compatible computer (not included) with HP Laserjet or Epson FX80 compatible printer.

Currently available Software: PCLX is supplied with two easy to use and powerful programs: PCwave and PCpitch as illustrated left.

Library routines including multichannel and direct to disc waveform storage are also available.

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PCLX

Interactive speech & laryngograph
analysis & display system

	INTRODUCTION
An overview. Introduction to programs: PCwave, PCpitch. Tutorials based on examples. Acquisition of new data.	**GETTING STARTED**
Working on perception and production with visual feedback. Ideas for therapy and teaching.	**APPLICATIONS**
Definitions, examples and discussion on interpreting waveforms, fundamental frequency data.	**INTERPRETATION**
Placing the electrodes. Making recordings. Adjusting gain controls. Organising and storing data. Disc filing systems. Copying files. Data bases.	**HINTS & TIPS**
User guide to the program commands and facilities. Derivation of measures and statistics.	**PROGRAMS**
How to install and configure the interface card and software. How to optimise performance. Connecting leads. Printers. Programmers guide.	**INTERFACE**
User guide and technical guide to your external sensing equipment e.g. Laryngograph Processor (PCLX)	**HARDWARE**
A guide to the literature.	**LITERATURE**
Sample texts. Your notes.	**NOTES**

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yellow
connect = y
blue to other
other to earth.

Telequipment 551B
① push in
DC and EXT trigger
② pull trigger level knob
out
③ Set Volts/div = 1
④ Time/div = 0.2 V
⑤ turn on Voicescope
Repeat + base on
⑥ Turn variable time/DIV
until 1 repeating line
until get ① step across.
⑦ ~~[illegible]~~

READ THIS FIRST

Using this manual

This is an installment of the manual. On the overall Contents page you will find marked, those sections to which the present installment relates.

We have chosen a ring binder presentation so that the manual can be

: tailored to individual requirements,
: updated and expanded
: used to collate your own notes and references.

We have planned the manual with both the new and experienced user in mind. A new user can progress through tutorials to familiarise with the software, installation of interface, use of external hardware and then to applications. For those with more experience we hope to have facilitated quick access to the information you need by:

: General contents page with brief description.
: Section contents with full description
: Side headings
: We have attempted to make each section self contained with references to other sections where necessary.
: The software itself contains much information: you should be able to find on each screen the information and options available to you.

If ever you are stuck, or require additional information you should phone us. If the equipment appears not to work arrange to have the phone beside your equipment. We will need to know the following information: Your serial number (Board and software should be the same), Your PC and operating system details and as accurate a description of the problem as possible.

We would appreciate comments and suggestions for future inclusion.

COPYRIGHT

PCLX is sold subject to copyright. The PCLX software is supplied to work with the board of the same serial number. Data acquisition is only possible when the serial numbers of the software and board correspond.

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Brief Overview

What is PCLX?

PCLX is the software component of a Laryngograph based interactive speech analysis and display system for IBM compatible personal computers (PC).

A complete system has three parts.

1. External sensing equipment involving any one or combination of the following:

   Portable Laryngograph.
   Laryngograph Processor Type "PC" or "PCLX".
   Voiscope.
   Electrodes or microphone.
   Other sensing systems e.g. glottal flow, nasality, airflow.

2. An Interface card which when installed in the PC provides a link between the sensing equipment and the computer.

3. Software: PCLX programs work with the external equipment and the interface to make it possible to acquire, display, analyze and store the signals. These programs provide the main system facilities: through them you select what data you want to acquire, analyse, display, save, load or play out. For this reason the manual is organised around these core PCLX programs.

How do I get started?

To get started for the first time, and on any future occasion when you wish merely to display or analyse data previously stored on disc, you do not need to install the interface card or any hardware; you can run the program on its own, on any PC (see 2.3)

To input data to the programs you will need to install the interface card and to connect up and know how to use some external hardware. Instructions on how to install the interface card and operate external hardware are given in the Interface section (4) of the manual. Once the interface is installed it can be forgotten. Once you have mastered the operation of your external hardware its use will be merely a question of selecting the signals you wish to display and adjusting the levels. From the program point of view inputting recorded signals is the same as inputting live signals. Some notes on making tape recordings are dealt with in a separate section.

Getting started with PCLX software.

Before you start

Requirements

It is best for you to be familiar with some basic operations of your PC and the Disc operating system (DOS version 3.0 or higher). E.g. you must know how to type in commands and operate the disk drives. If you are not clear how to do this please refer to one of the many beginners guides to DOS available in the larger bookstores (e.g. published by QUE). However, you may be able to get started by following the instructions below.

We assume that your principal floppy disc drive is drive A: and your hard disc drive C:, should this not be the case simply substitute the drive names appropriate to your system.

Conventions

In the notes that follow the following conventions apply:

Commands or words that you are to type in are written in **Bold.**
Where you are required to press a particular key it will be enclosed in **<>** e.g. **<Enter>** means press the "Enter" key.

Installation

The software is supplied on either 5.25" or 3.5" floppy discs. If you do not install on your hard disc you are advised to make a copy of the disc and keep the original in a safe place.

Installing on hard disc.

If you have a hard disc you will probably want to install PCLX on it.

Ensure that you are in the root directory (C:\>), by typing

```
CD\   <Enter>
```

Insert program disc,

Type

```
     A: <Enter>

     INSTALL C:     <Enter>
```

The Install program will create a directory PCLX on your hard disc (in this case disc C:) and copy the PCLX programs into it.

Running PCLX

Running PCLX

(1) From your hard disc

Type

```
    CD PCLX       <Enter>
    PCLX          <Enter>
```

(2) Direct from floppy.

Insert floppy disc (A:) and at the ">" prompt:

Type

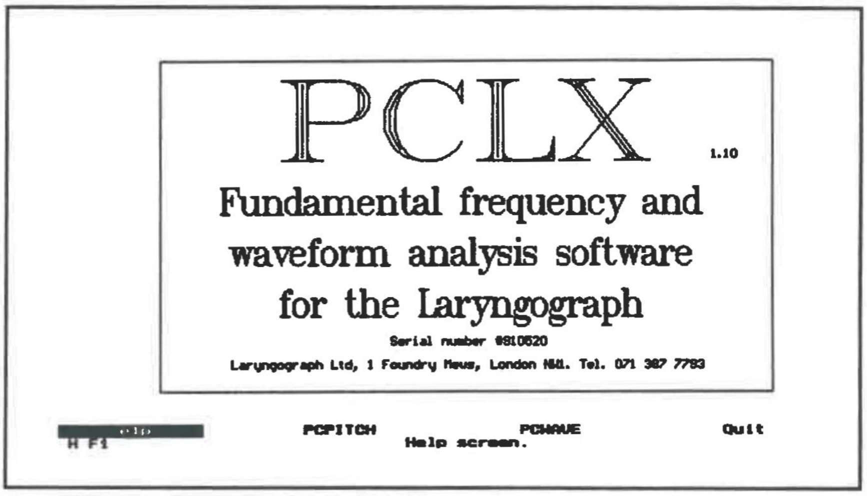
```
    A:            <Enter>

    CD PCLX       <Enter>
    PCLX          <Enter>
```

Diagnostics

The PCLX programs will now be loaded and start to run. On start up, diagnostic software runs to check the functioning of the PCLX interface card and the PC. This will happen every time; it is quick and will only require action if a fault is discovered. If an error message is displayed it will usually inform you of the required action. You may have to refer to the sections in this manual on installing the interface.

Main Menu

The main PCLX menu will then appear on screen.



PCLX 1.10

Fundamental frequency and
waveform analysis software
for the Laryngograph

Serial number #810620

Laryngograph Ltd, 1 Foundry Mews, London NW1. Tel. 071 387 7793

Help screen.

Using PCLX

We recommend that you go through this section of the manual while sitting at the computer, after starting the PCLX system.

Making a selection

The system has been designed to be easy to use and has evolved with the help of feedback from users.

There are usually three ways of selecting a menu option or command and adjusting settings. You can choose the method you prefer or use a mixture of all three:

1. By using the cursor keys ←↑↓→ to move the highlight box over the required option and pressing **<Enter>**.

2. By pressing the appropriate Function key.

3. By pressing the appropriate quick key, which is usually the initial letter of the command e.g. **<a>** for acquisition. On the main menu the quick key is highlighted within the word in yellow.

Keys

The following keys are used throughout the system and have consistent functions.

←↑↓→, the cursor keys, are associated with movement; the precise action varies according to the chosen option: within a menu the keys will move the highlight box; within the ZOOM option they will move the sides and position of the window; within the CURSOR option they will move the cursor; within PAN they move the waveforms from side to side.

<Enter> is used to start a process e.g. via a highlighted option or to complete acquisition.

<Ctrl> (control, also referred to by the ^ character) is used in conjunction with the cursor keys to speed up various displays and with the Enter key to alter its function.

<Esc> stops the immediate process or take you back one step in the menu structure.

<Tab> is used to switch between two screen windows e.g. between upper and lower waveform or upper and lower Fx Target displays.

<Print Screen> will print the currently displayed screen.

PCwave

What is PCwave?

PCwave is a program for the acquisition, storage, display, manipulation, measurement and printing of waveforms. The standard program displays two signals, usually the speech pressure waveform (Sp) on the top and the Laryngograph output waveform, (Larynx excitation = Lx) on the bottom. There are two "live" viewing modes: one with a slow time base which is useful for observing whole words or sentences, the other with a fast time base useful for real time cycle by cycle observation. Once the waveforms have been acquired it is possible to zoom in or out, to pan through, make adjustments and measurements, to replay, print and store on disc.

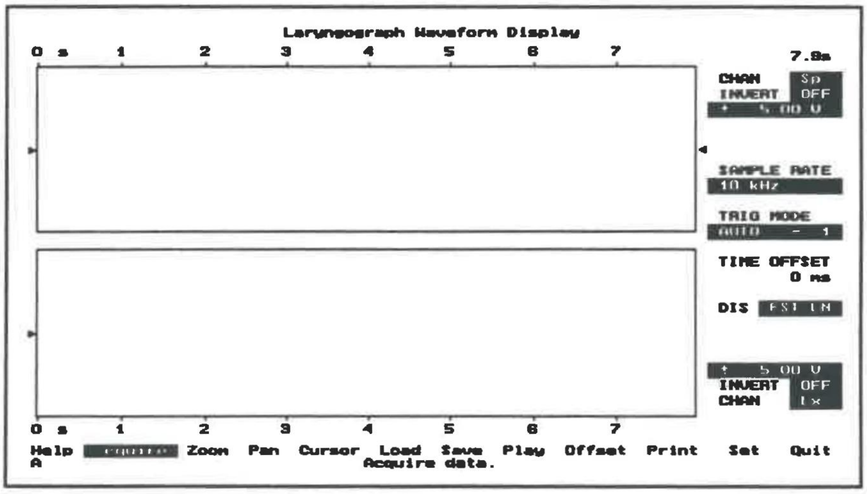
How do I get started?

Included with the program disc are two examples of a stored waveform; one of a stored screen, the other of the whole memory. What follows is a short tutorial which takes you through loading and manipulating the stored waveform screen. The same procedures can be applied to the full memory version, but being much longer it takes longer to load - just how long depends on the speed of you PC and disc drives!

Select PCwave

If you have not already done so start PCLX as described on 2.4. Highlight PCwave on the main menu using ← → and pressing **`<Enter>`.**

The PCwave title screen will appear followed by the PCwave display and menu screen.



Laryngograph Waveform Display

7.8s

CHAN Sp
INVERT OFF
+ 5.00 V

SAMPLE RATE 10 kHz

TRIG MODE AUTO - 1

TIME OFFSET 0 ms

DIS FST LN

+ 5.00 V
INVERT OFF
CHAN Lx

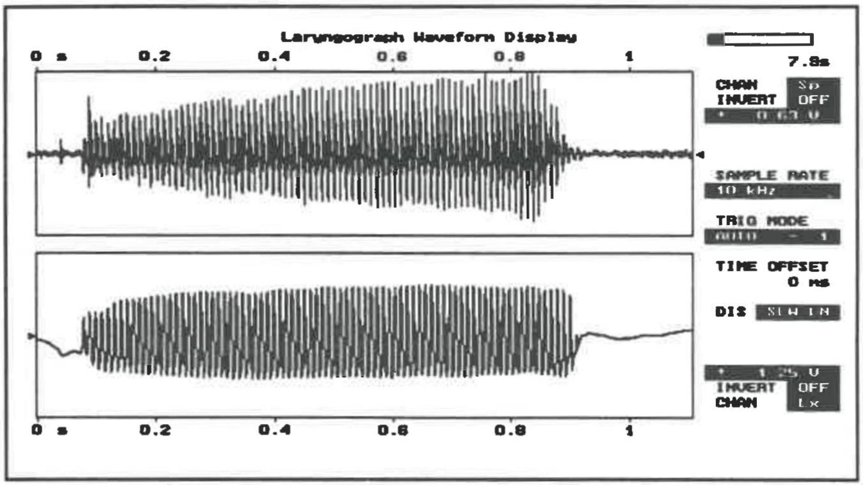
Acquire data.

Most of the screen comprises two blue windows for the waveforms with the horizontal axis marked in seconds. Down the right hand side are a collection of settings which comprise the control panel. Along the bottom is the PCwave menu.

Loading a waveform from disc.

Move the highlight box over LOAD and press **<Enter>**.
Type
  LxData   **<Enter>** to chose the LxData directory.
The file table now appears with one highlighted file. Select the file "SAMPLE" using the cursor and pressing **<Enter>**. (EXAMPLE is the full memory version).
The waveform is loaded in "slow" timebase mode - a maximum of approximately 8 seconds of each waveform is shown at this sample rate although the exact amount will depend on the software configuration of your PC (for a discussion of this see the Interface section). SAMPLE is just over 1 second long.

Slow timebase display



CHAN Sp
INVERT OFF
+ 0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS SLW LN
+ 1.25 V
INVERT OFF
CHAN Lx

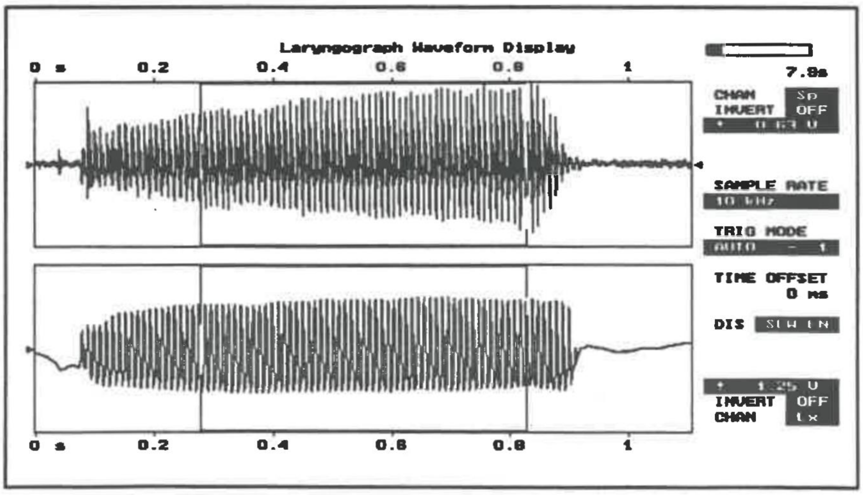
PCwave display and menu

Zoom

How can I see more detail?

Highlight ZOOM using ← → and press **<Enter>**.
Note:

1. The menu line is replaced by an information line displaying Keyboard control options.
2. A zoom window defined by two "cursors" appears over each waveform.



CHAN Sp
INVERT OFF
+ 0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS SLW LN
+ 1.25 V
INVERT OFF
CHAN Lx

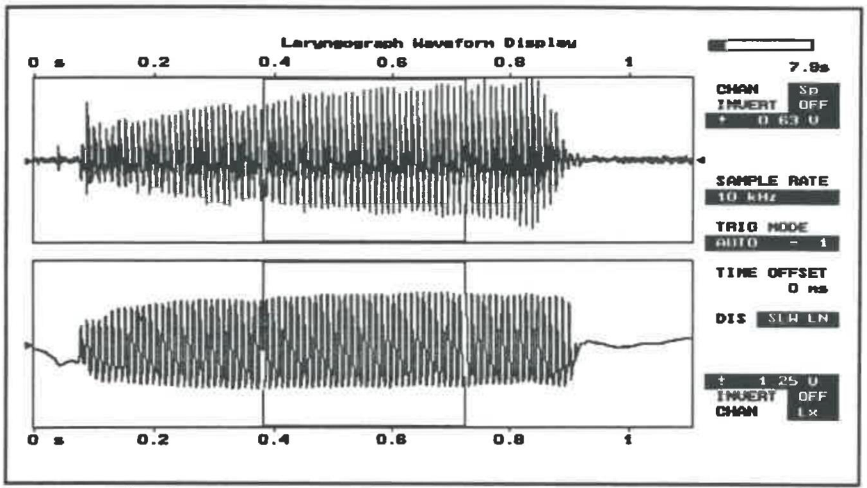
Adjusting the Zoom window

The zoom window can be moved right → and left ←, shrunk ↓ and enlarged ↑.

Pressing **<Enter>** will zoom the windowed section which will be expanded to fill the screen.

Pressing **<Ctrl> <Enter>** will reverse that process: the screen will compress into the windowed section.

Adjust the window to frame the central section of the waveform as shown in the next figure.

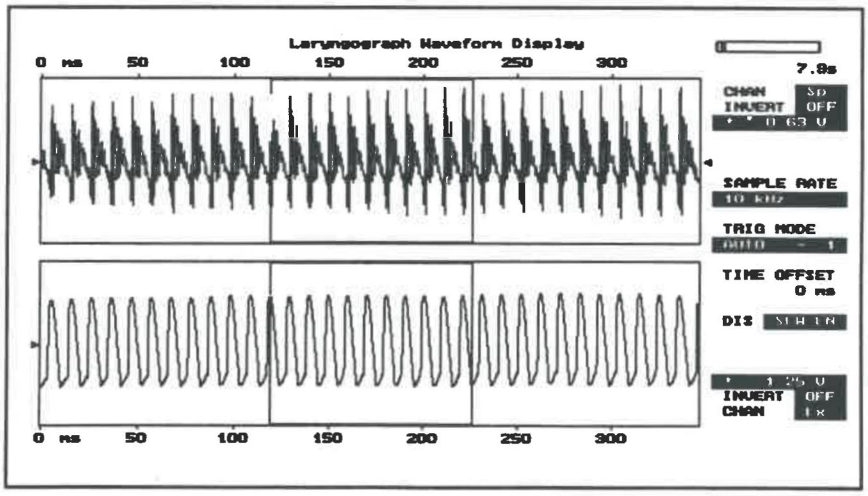

Laryngograph Waveform Display
0 s
0.2
0.4
0.6
0.8
1

7.9s
CHAN Sp
INVERT OFF
± 0.63 V
SAMPLE RATE 10 kHz
TRIG MODE AUTO - 1
TIME OFFSET 0 ms
DIS SLW LN
± 1.25 V
INVERT OFF
CHAN Lx

Zoom windows

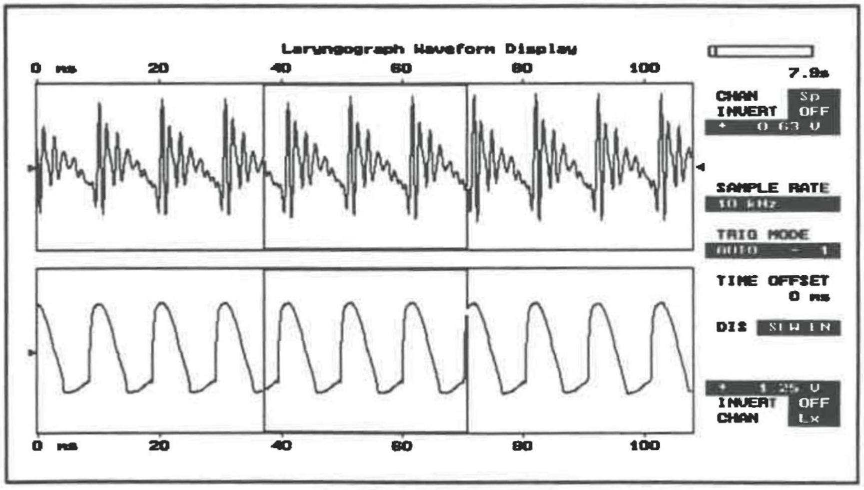
Press **<Enter>** to zoom in

Zoom in


Laryngograph Waveform Display
0 ms
50
100
150
200
250
300

7.9s
CHAN Sp
INVERT OFF
± 0.63 V
SAMPLE RATE 10 kHz
TRIG MODE AUTO - 1
TIME OFFSET 0 ms
DIS SLW LN
± 1.25 V
INVERT OFF
CHAN Lx

Press **<Enter>** again to zoom in closer still


Laryngograph Waveform Display
0 ms
20
40
60
80
100

7.8s
CHAN Sp
INVERT OFF
+ 0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS SIG LN
+ 1.25 V
INVERT OFF
CHAN Lx

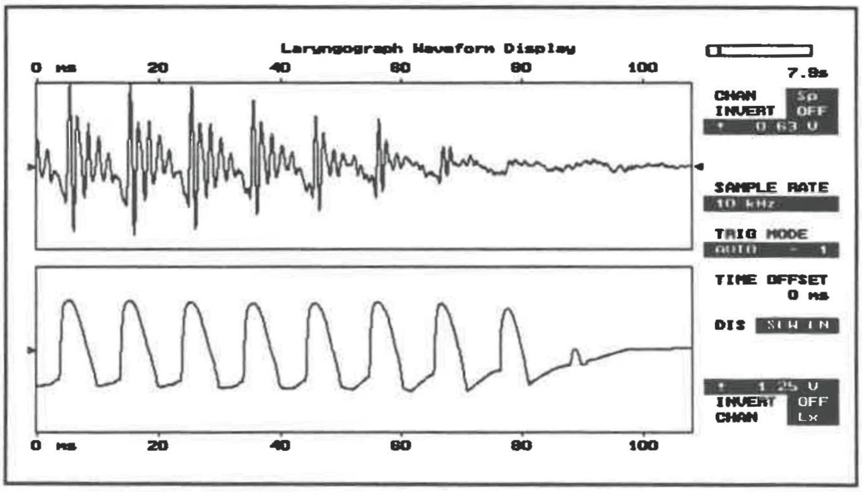
Pan

Once I have zoomed in how can I move along a waveform?

Press **<p>**, this enters the pan screen directly from the zoom screen.

Press → to move the window right along the waveform - **<Ctrl>** → moves the window faster.

Repeat this keypress several times until you reach the end of this section of voiced speech.

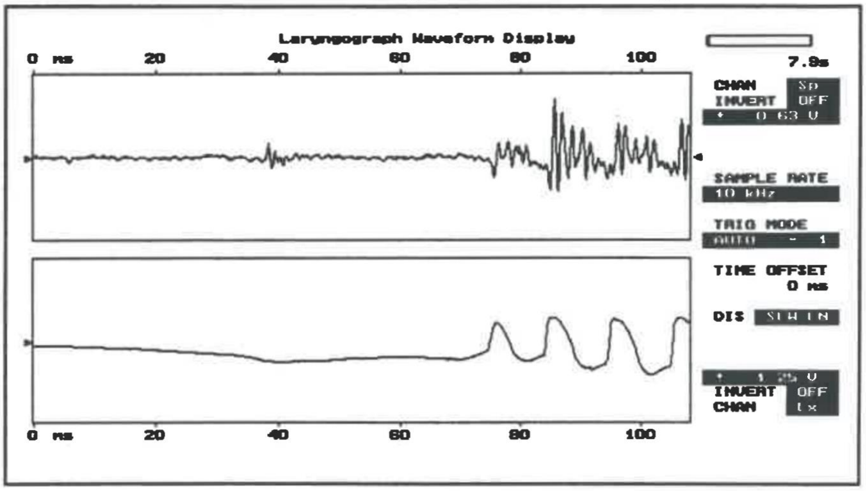

Laryngograph Waveform Display
0 ms
20
40
60
80
100

7.8s
CHAN Sp
INVERT OFF
+ 0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS SIG LN
+ 1.25 V
INVERT OFF
CHAN Lx

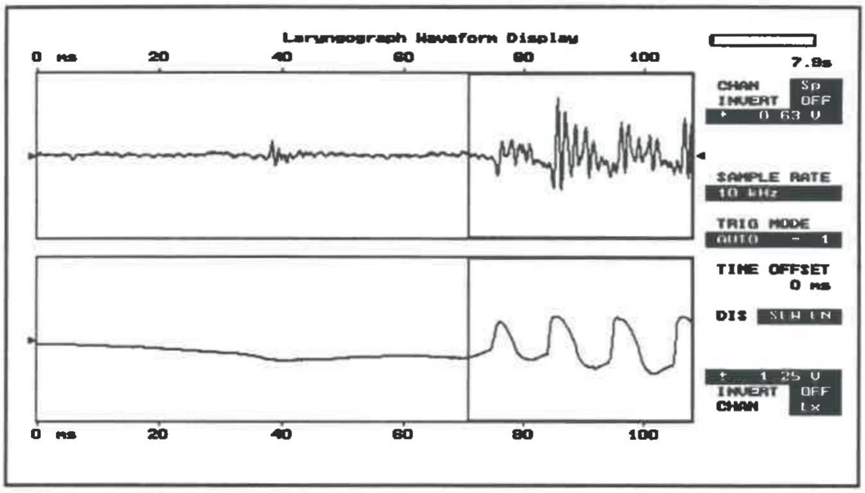
Notice the memory indicator in the top right hand corner of the display which displays the position of the current window in relation to the complete waveform.

Press **<End>**	this moves the window and indicator the end (extreme right).
Press **<Home>**	this moves the window and indicator to the start (extreme left).

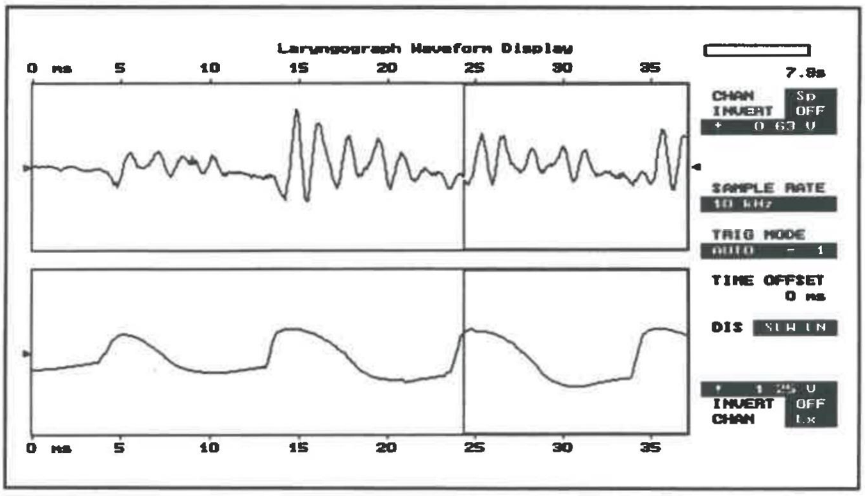
The screen will now show the beginning of the sample:


Laryngograph Waveform Display
0 ms
20
40
60
80
100
7.9s
CHAN Sp
INVERT OFF
+ 0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS
+ 1.25 V
INVERT OFF
CHAN Lx

Press <Z> to re-enter Zoom. Frame the end section:


Laryngograph Waveform Display
0 ms
20
40
60
80
100
7.9s
CHAN Sp
INVERT OFF
+ 0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS
+ 1.25 V
INVERT OFF
CHAN Lx

Press **<Enter>**


Laryngograph Waveform Display
0 ms
5
10
15
20
25
30
35
7.9s
CHAN Sp
INVERT OFF
+ 0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS
+ 1.25 V
INVERT OFF
CHAN Lx

Selecting the active window

Press **<Tab>** to switch between the top and bottom displays.Notice that the highlighted border changes to indicate the active window.

Using this feature it is possible to make adjustments which only affect the active window.

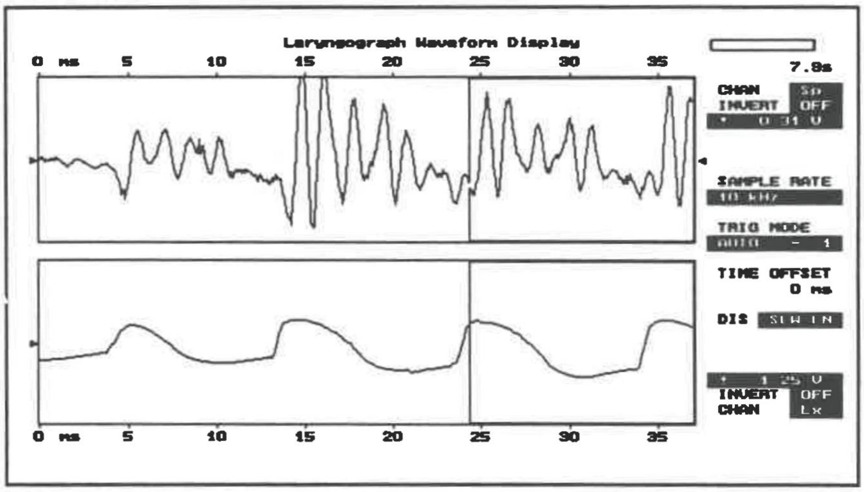
Now use **<Tab>** to make the Sp window active.

How can I adjust the waveform size ?

Sizing the waveform

With the Sp window active,

Press **<PgUp>**



CHAN Sp
INVERT OFF
± 0.31 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS SLW IN
± 1.25 V
INVERT OFF
CHAN Lx

Notice how the displayed speech waveform is increased in size and how the measure of full screen sensitivity is adjusted accordingly (from +/-0.63v to +/-0.31v).
Press **<PgDn>** to restore

Now press **<Tab>** to change window and repeat for the Lx waveform.

Press **<PgUp>**
Press **<PgDn>** to return
You can adjust the full screen sensitivity between +/- 5v and +/- 9.77mV.

Now press **<Esc>** to return to the main display screen.

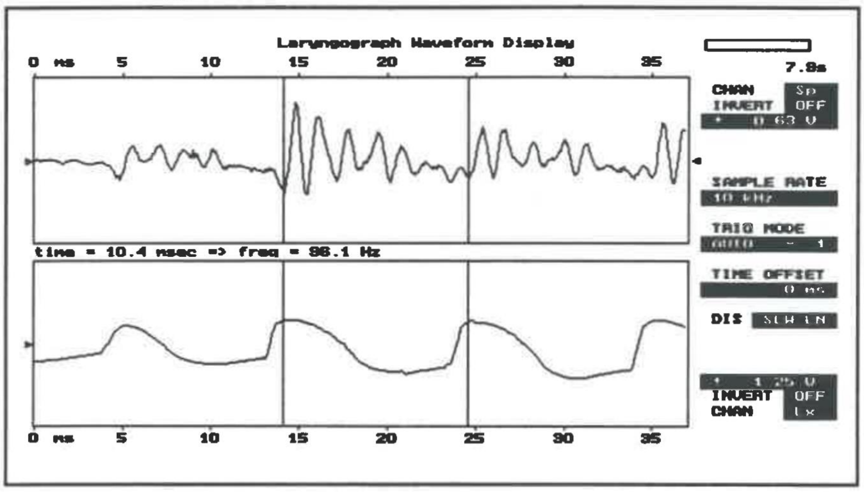
Measurements

How can I measure the waveform?

From the main display screen highlight CURSOR and press **`<Enter>`**.

Note:
1. The menu line is replaced by an information line displaying Keyboard control options.

2. 2 cursors appear on each waveform.



Laryngograph Waveform Display

time = 10.4 msec => freq = 96.1 Hz

CHAN Sp
INVERT OFF
+ 0.63 V
SAMPLE RATE 10 kHz
TRIG MODE AUTO - 1
TIME OFFSET 0 ms
DIS SCR LN
+ 1.25 V
INVERT OFF
CHAN Lx

How can I move the cursors?

Press ←
the left cursor moves to the left.
Press →
the the left cursor moves to the right.

`<Ctrl>` ← and **`<Ctrl>`** → may be used to move the cursors faster.

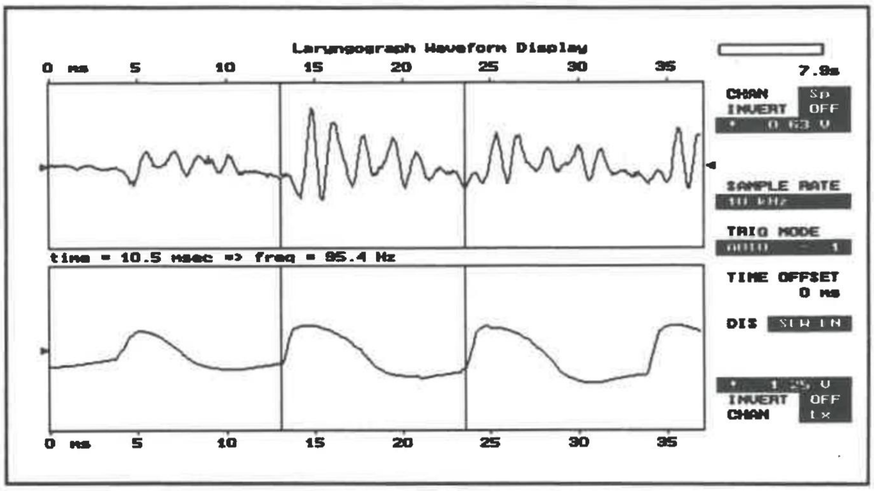
Select the active cursor using **`<1>`** for the left and **`<2>`** for the right.

<1> selects cursor 1 (left) and <2> selects cursor 2 (right).

In the middle of the screen, between the windows, are measures of the difference between the cursors expressed in time and frequency.

The next figure shows the cursors positioned to measure the time difference between successive vocal fold closures. The frequency measurement is the fundamental frequency at this point.

This technique can be used to give a measure of voice onset times by positioning the left cursor at the start of the burst in the speech waveform and the right cursor over the first Lx closing period.


Laryngograph Waveform Display
0 ms
5
10
15
20
25
30
35
7.9s
CHAN Sp
INVERT OFF
0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS
1.25 V
INVERT OFF
CHAN Lx

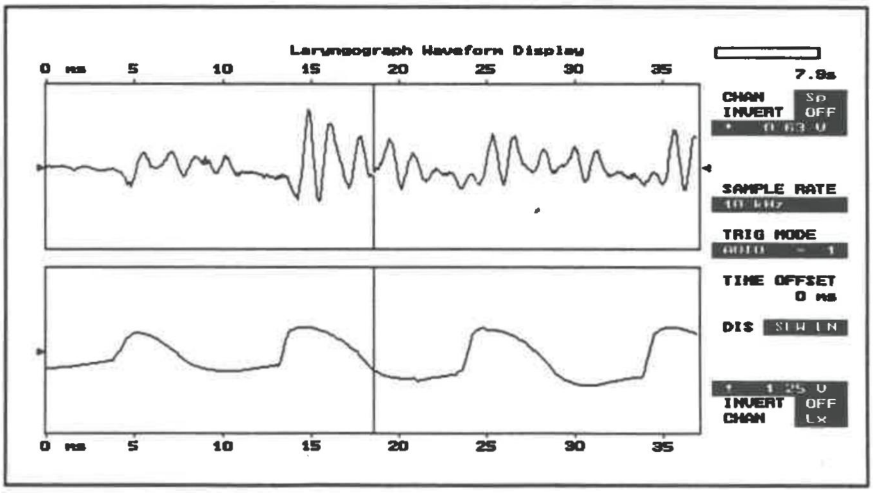
time = 10.5 msec => freq = 95.4 Hz

You will notice that the cursors, when placed on the closing phase of Lx, do not correspond exactly with the main excitation of Sp. This is due to delay caused by the length of path between the microphone and the vocal folds, which will vary from person to person. (If the speed of sound is 340m/sec then it will take 1ms to travel 34cm).

`Offset`

Offset allows you to shift the waveforms relative to each other to compensate for the timing difference discussed above.

Now press **<Esc>** to return to the main display screen.
From the main display screen highlight OFFSET and press **<Enter>**.


Laryngograph Waveform Display
0 ms
5
10
15
20
25
30
35
7.9s
CHAN Sp
INVERT OFF
0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO - 1
TIME OFFSET
0 ms
DIS
1.25 V
INVERT OFF
CHAN Lx

Note:

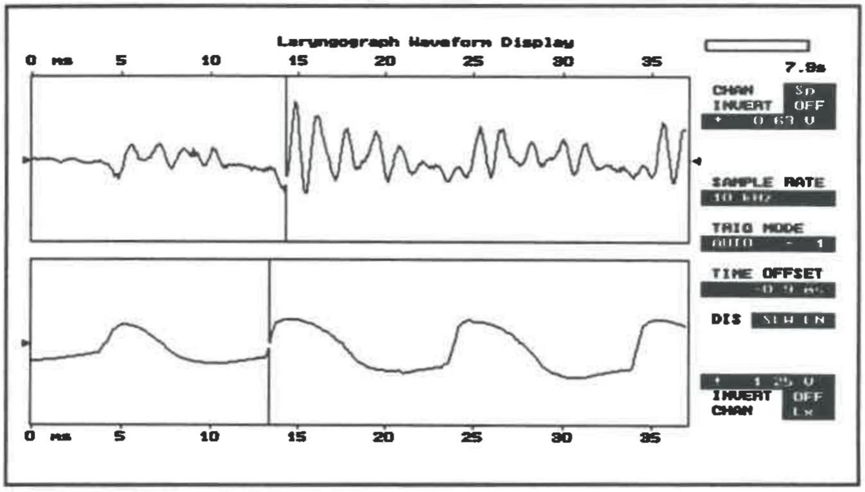
1. The menu line is replaced by an information line displaying Keyboard control options.

2. A single cursor appears on each waveform.

An offset is achieved either by positioning the cursors in the windows to known or calculated offset values or by positioning them on events which are known to occur simultaneously.

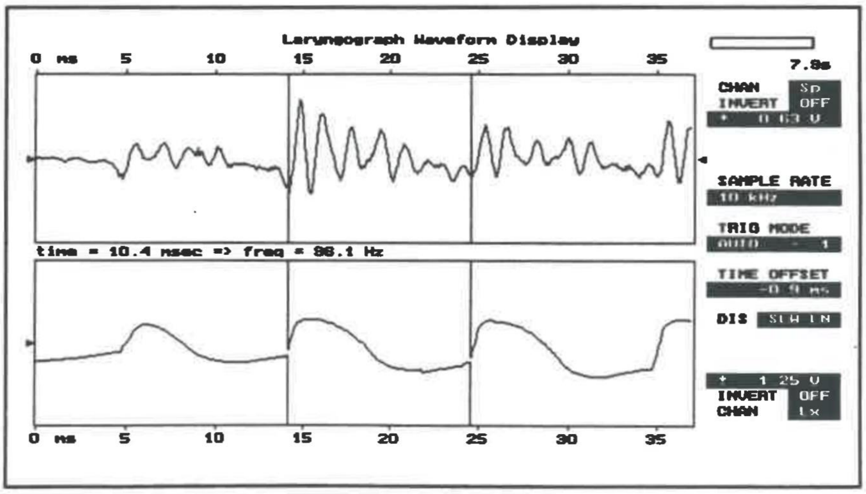
The active, brighter, cursor is in the top window; to move between the top and bottom windows use **`<Tab>` `or`** ↑ and ↓. ← and → are used to position the active cursor on the waveform - **`<Ctrl>`** ← and **`<Ctrl>`** → may be used to move the cursors faster.

In this example we position the lower cursor over the closing period of the vocal folds, the abrupt nature of which is responsible for delivering the main excitation to the vocal tract. We have positioned the upper cursor over the response to this excitation at the start of the major positive going excursion in the speech pressure waveform. Notice that the value given in the time offset slot changes as you move the cursors.



```
CHAN        Sp
INVERT      OFF
+  0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO  -  1
TIME OFFSET
-0.9 ms
DIS  SLW LN
+  1.25 V
INVERT      OFF
CHAN        Lx
```

Pressing **`<Enter>`** will realign the waveforms so that these two points are now in direct vertical alignment. The value of the time shift is noted in the Time offset slot. You can check this using CURSORS.



```
time = 10.4 msec => freq = 96.1 Hz
```

```
CHAN        Sp
INVERT      OFF
+  0.63 V
SAMPLE RATE
10 kHz
TRIG MODE
AUTO  -  1
TIME OFFSET
-0.9 ms
DIS  SLW LN
+  1.25 V
INVERT      OFF
CHAN        Lx
```

PCpitch

What is PcPitch?

PCpitch is a program for the acquisition, display and analysis of the fundamental frequency of voiced speech. Fundamental frequency is the acoustic correlate of pitch/intonation, a perceptual phenomenon.
PCpitch allows you to measure the period between pulses marking the period between vocal fold closures during voiced speech. These pulses are derived either from the Laryngograph waveform or from a fundamental period based on the microphone speech pressure waveform.

What can I do with PcPitch?

You can view intonation (pitch) patterns in real time; work interactively using target displays; perform analysis and statistics on significant lengths of continuous speech to examine range, regularity and measures of central tendancy in fundamental frequency distributions.

How do I get started?

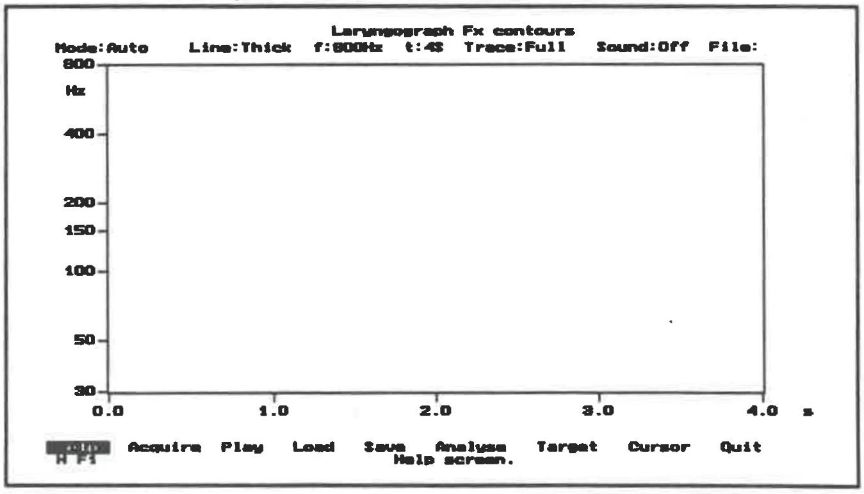
Included with the program disc is an example data file. What follows is a tutorial which takes you through loading and displaying the example in PcPitch.

If you have not already done so type:

```
CD PCLX
PCLX <Enter>.
```

The PcPitch title screen will appear followed shortly by the PcPitch main display screen.

PcPitch main display screen



```
Laryngograph Fx contours
Mode:Auto     Line:Thick   f:800Hz   t:4S   Trace:Full    Sound:Off   File:
```

```
Help screen.
```

PcPitch Features

- The main window is used to display frequency (log scale) against time.
- The second line at the top of the screen shows the default options.
- The line below the main window shows the available functions.
- The bottom line gives information on the currently selected function and the keys which access it.

Loading data from disc

Loading from disc

Use the cursors to highlight LOAD, press **<Enter>**.

Type **TxData** **<Enter>** to select data directory.

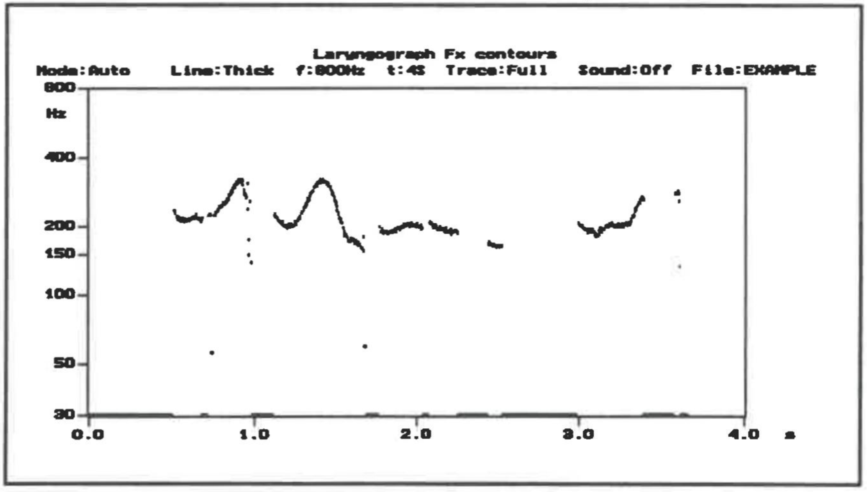
The PCLX disc filing table will appear with one file highlighted. Highlight EXAMPLE using the cursor keys and Press **<Enter>** to select the file.

The file will load, this may take some time from the floppy disc, and the screen will appear with the Fx contour present when the file was saved. ("Working" refers to data analysis which takes place following loading.)

Play

Highlight PLAY **<Enter>**

The Fx contour in memory will now be played through.



Laryngograph Fx contours

Mode:Auto Line:Thick f:800Hz t:4S Trace:Full Sound:Off File:EXAMPLE

<F2> or **<n>** will turn on/off the sound.
<Space> will pause and resume when pressed again.
<Enter> will stop playing.

Press **<Enter>** to stop playing.

Setting display options

The line along the top of the screen can be used to set some features of the display.
Press
<↑> to move the highlight to the top of the screen
<← →> move the highlight along
<↓>returns the highlight to the menu line at the bottom.

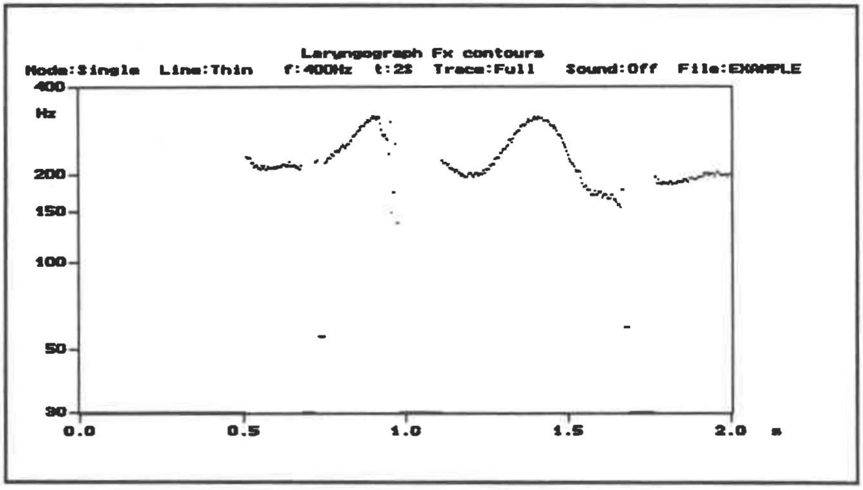
Highlight MODE: this is currently set to AUTO
pressing **<Enter>** will change this to SINGLE,
pressing **<Enter>** again will return it to AUTO
Most of the settings work like this.

Display options

Highlight MODE and set to SINGLE
Highlight LINE and set to THIN
Highlight f: the default is 800 Hz; pressing **<Enter>** changes to 400 Hz; pressing <Enter> again, returns to 800 Hz.
Highlight t: the default is 4secs, pressing **<Enter>** once selects 6 secs, pressing **<Enter>** again selects 2 secs, pressing **<Enter>** again sets back to 4 secs.
Set to 2 secs.
TRACE: Full indicates that the whole screen is being used c.f. UPPER and LOWER when in TARGET.
SOUND: set to ON
FILE: names the currently loaded file.

Now return the highlight to the menu line **<↓>**.
Highlight PLAY **<Enter>**

One screen full of the file will now be played with the new settings.

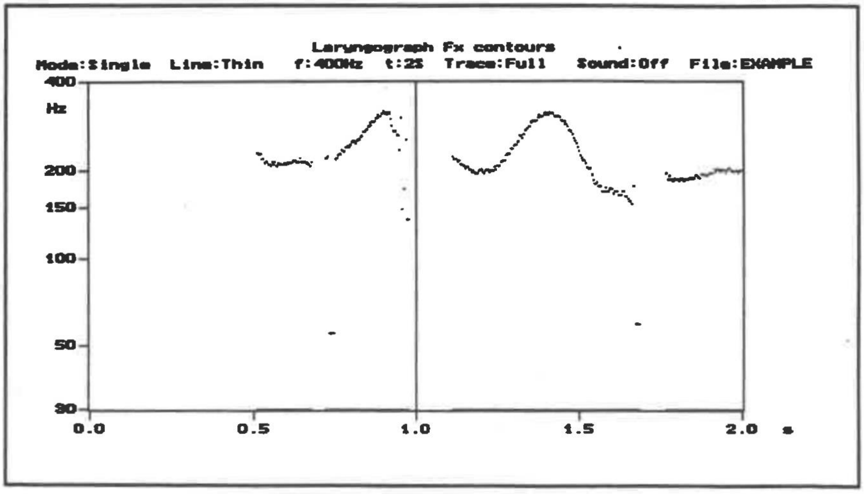

Laryngograph Fx contours
Mode:Single Line:Thin f:400Hz t:2S Trace:Full Sound:Off File:EXAMPLE

Cursor

Press **<Esc>** to return to the main menu
Highlight CURSOR **<Enter>**

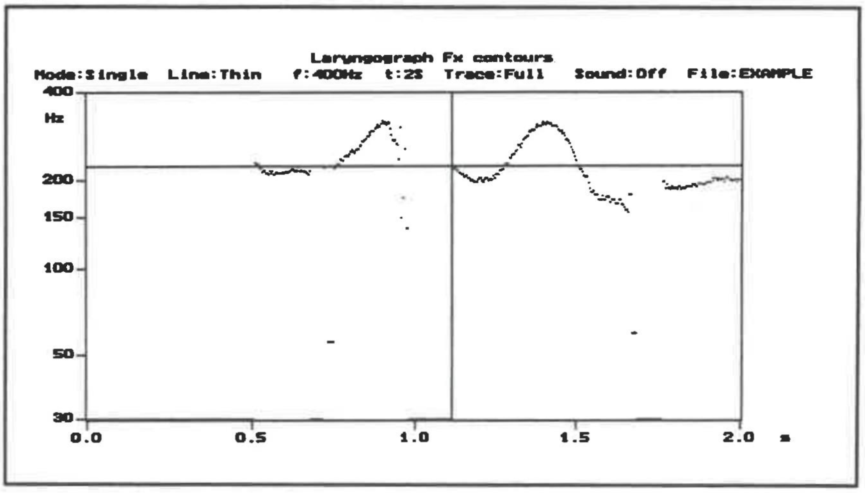
Measure

Press **<Enter>** again to select MEASURE. A cursor appears:


Laryngograph Fx contours
Mode:Single Line:Thin f:400Hz t:2S Trace:Full Sound:Off File:EXAMPLE

Cursor measurement

<← →> can be used to move the cursor and pressing **<Ctrl>** at the same time will speed up the movement.
When the cursor reaches a section of voiced speech the cursor will appear as cross hairs locating a particular pixel - a point of light on the screen. A measure of the period and frequency will appear in the bottom line.



Laryngograph Fx contours

Mode:Single Line:Thin f:400Hz t:2S Trace:Full Sound:Off File:EXAMPLE

Adjusting the dotted horizontal markers

<Esc> to return to the cursor sub menu.

Highlight MARKERS **<Enter>**. This removes the dotted horizontal markers from the screen. Press **<Enter>** again to return them.

Highlight UPPER **<Enter>**.
This option enables you to adjust the position of the upper horizontal dotted marker, using the cursor keys.

LOWER allows you to adjust the position of the lower. You may find this useful in setting a target range.

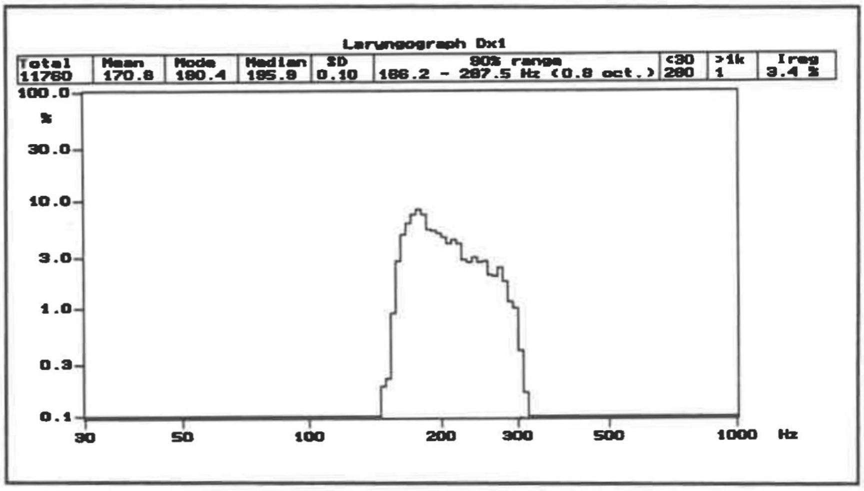
<Esc> back to the main menu

Analyse

Move the highlight to ANALYSE and then **<Enter>**

The Dx1 display appears:

Dx1
Ist order
dist.

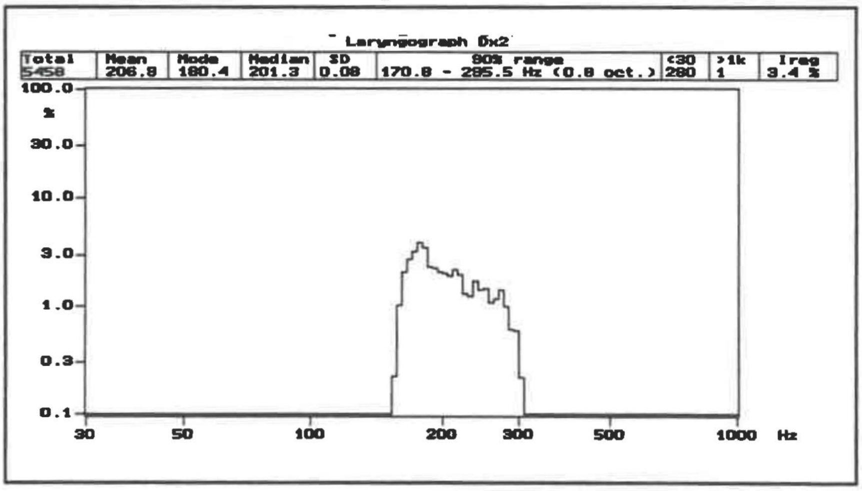


Laryngograph Dx1

Total	Mean	Mode	Median	SD	90% range	<30	>1k	Ireg
11760	170.8	180.4	185.9	0.10	166.2 - 287.5 Hz (0.8 oct.)	280	1	3.4 %

Move the highlight to Dx2 and press **<Enter>**.

Dx2
2nd order
dist.

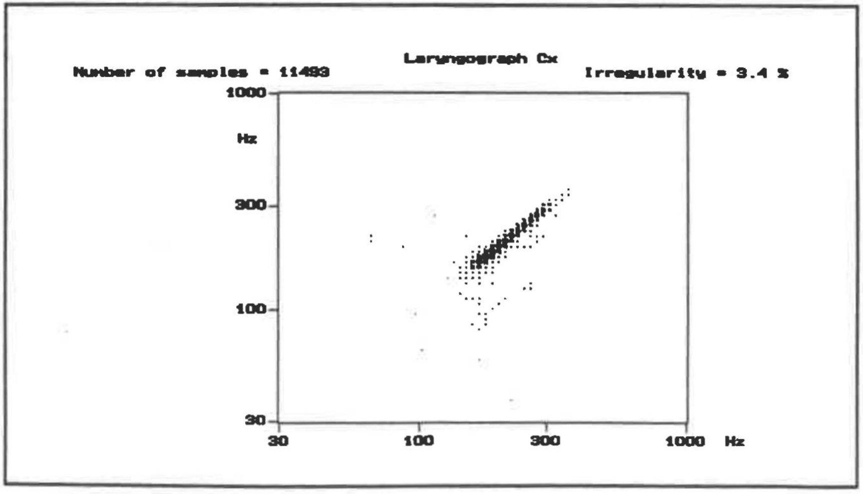


Laryngograph Dx2

Total	Mean	Mode	Median	SD	90% range	<30	>1k	Ireg
5458	206.9	180.4	201.3	0.08	170.8 - 285.5 Hz (0.8 oct.)	280	1	3.4 %

Move the highlight to Cx and press **<Enter>**.

Cx
Cross plot



Laryngograph Cx

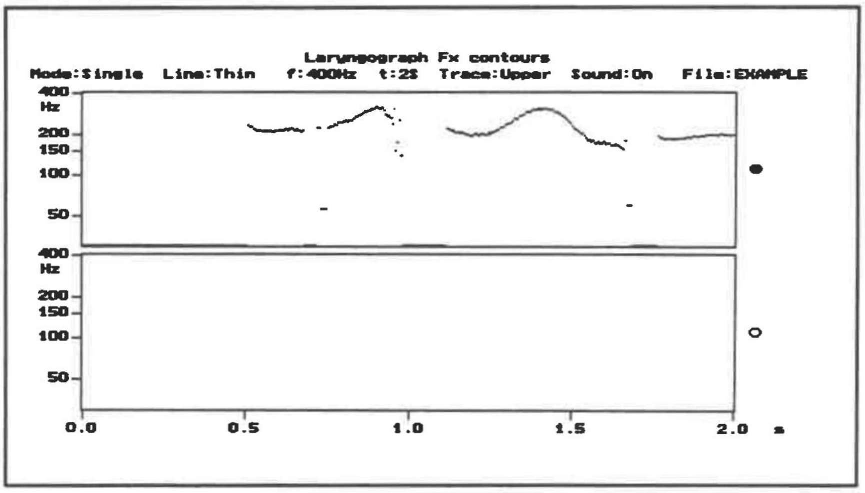
Number of samples = 11493

Irregularity = 3.4 %

Target display

From the main menu highlight TARGET **`<Enter>`**

The screen is now divided into two Fx contour display windows. Highlight PLAY **`<Enter>.`**



Laryngograph Fx contours

Mode:Single Line:Thin f:400Hz t:2S Trace:Upper Sound:On File:EXAMPLE

The active window is selected by **`<TAB>`** and indicated by the green "light" on the right hand side of the window.

Each of the windows can be used independently to input and view data (for example one for therapist and one for client) and for analysis. Data can be transferred between the upper screen and the full screen (highlight TARGET **`<Enter>`**`).` When switching between FULL and TARGET you will have to PLAY before the data is displayed. When loading from disc the arrangement is that when loading into the same window as existed when the data was stored the Fx contour existing at the time will be displayed; when loading into a different window you will have to PLAY before the data is displayed.

The rules and options for use of each window is the same as for full screen.

Target will be discussed again in PCpitch acquisition.

Acquisition of Live Waveforms

Requirements

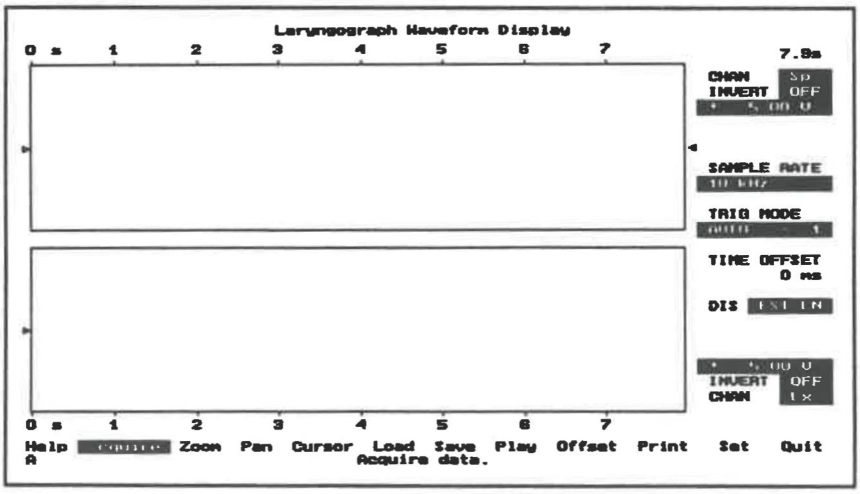
- PCLX V1. software installed as detailed in the previous section.
- PCLX Interface card installed and configured as described in the Interface section.
- External sensing equipment e.g. Laryngograph Processor(PCLX), Laryngograph, microphone etc. connected to the interface card.

In the tutorial which follows we assume that:

- You are familiar with the software having previously run through the familiarisation section.
- You are familiar with the operation of your external sensing equipment e.g. setting of switches and gain controls. If this is not so, please refer to the hardware section for guidance.
- The PCLXtest diagnostics program described in the Interface section has not reported any errors.

If you have not already done so load and run PCLX, select PCwave. The PCwave title screen will appear briefly followed by the main display and menu screen.

Main menu and display



CHAN Sp
INVERT OFF
± 5.00 V
SAMPLE RATE 10 kHz
TRIG MODE AUTO - 1
TIME OFFSET 0 ms
DIS EXT IN
± 5.00 V
INVERT OFF
CHAN Lx

A
Acquire data.

Check sensing equipment

Check that your external sensing equipment is turned on and that the electrodes and microphone are in position and that the gain controls are reasonably adjusted (e.g. at 12 o'clock). On the Lx Processor both green voicing indicator lights should illuminate when you voice.

check settings

If you have just selected PCwave the screen will contain the default settings. If you have been using PCwave to look at stored waveforms then the settings may have been altered. Check that the sample rate is set to 10KHz and that the sensitivity of both windows is +/- 5v.

Set the highlight over ACQUIRE.

Viewing modes: SHORT LONG

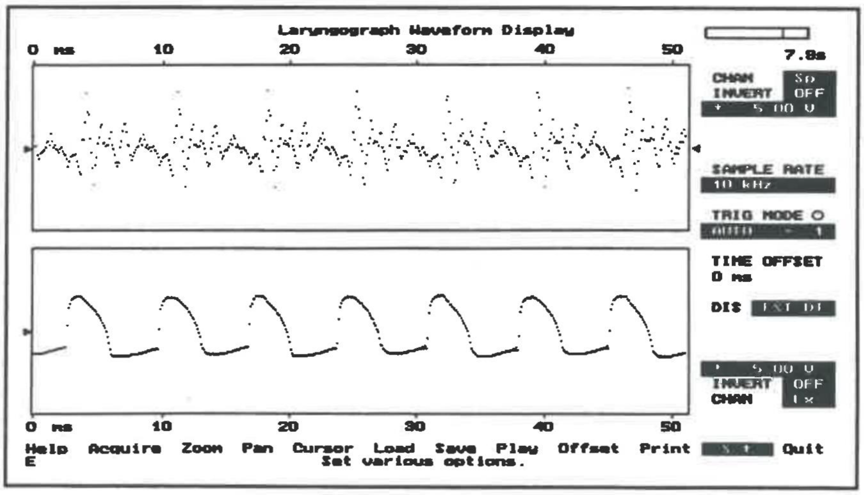
There are two live viewing modes: SHORT with a time base of 50ms at this sample rate and LONG with a time base of between 6 and 8 seconds depending on the sample rate and the software configuration of your PC (see the interface section for a discussion of this). You can switch between SHORT and LONG time base by pressing <S> any time while sampling is occurring.

Press `<Enter>`

Notice that the menu line changes to an information line giving you the options available to you.

SHORT

When you voice you should see something like this, with the SHORT time base setting:



Laryngograph Waveform Display

7.8s

CHAN Sp
INVERT OFF
+ 5.00 V

SAMPLE RATE
10 kHz

TRIG MODE O
AUTO + 1

TIME OFFSET
0 ms

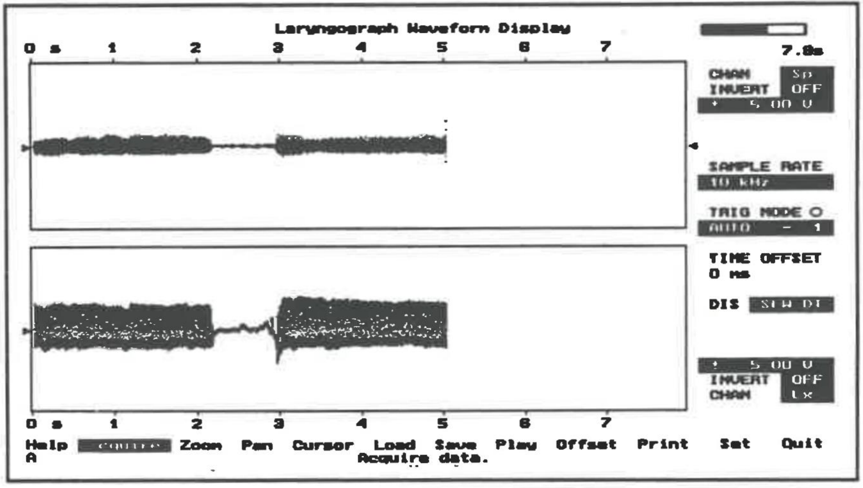
DIS EXT DI

+ 5.00 V
INVERT OFF
CHAN Lx

Set various options.

LONG

If you see something like the following, you are in the long time base setting. Switch to SHORT by pressing **<S>**.

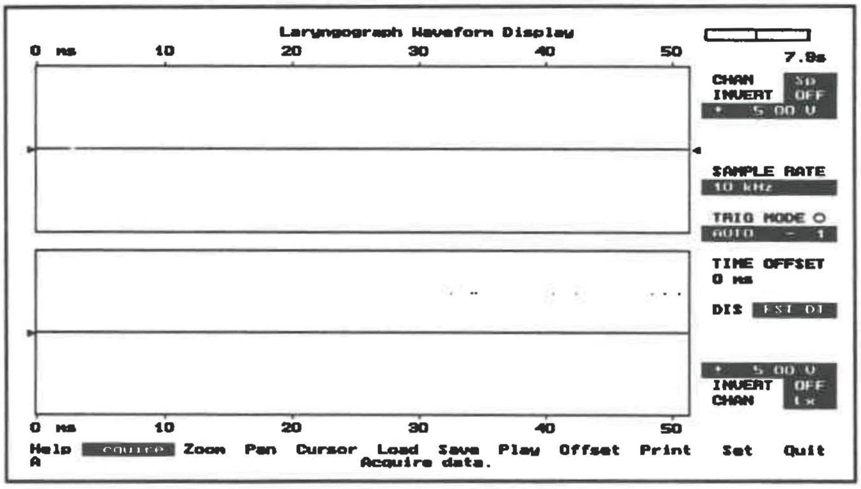

Laryngograph Waveform Display
0 s
1
2
3
4
5
6
7
7.8s
Help
A
Acquire
Zoom
Pan
Cursor
Load
Save
Play
Offset
Print
Set
Quit

CHAN Sp
INVERT OFF
+ 5.00 V
SAMPLE RATE
10 kHz
TRIG MODE ○
AUTO - 1
TIME OFFSET
0 ms
DIS SLW DT
+ 5.00 V
INVERT OFF
CHAN Lx

Acquire data.

Check external sensing/ connections

If you see something like the following while you are voicing it may be that your external sensing equipment is switched off, not connected, the gain too low, or the input set to TAPE.

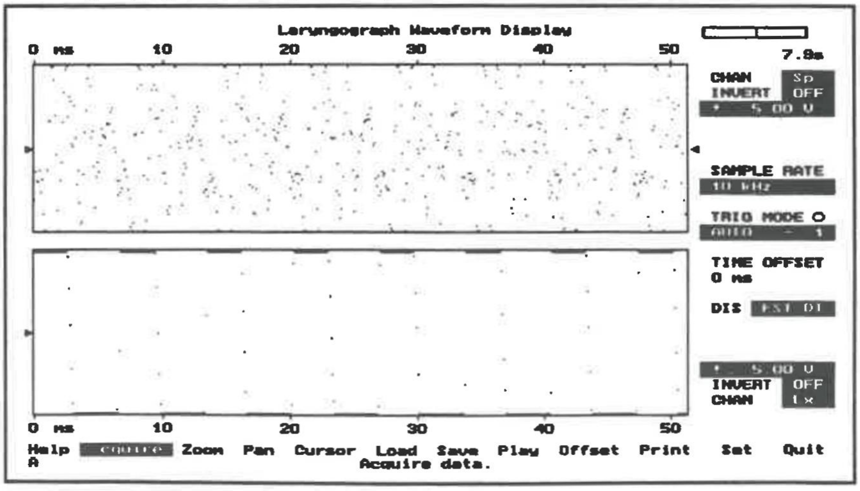

Laryngograph Waveform Display
0 ms
10
20
30
40
50
7.8s
Help
A
Acquire
Zoom
Pan
Cursor
Load
Save
Play
Offset
Print
Set
Quit

CHAN Sp
INVERT OFF
+ 5.00 V
SAMPLE RATE
10 kHz
TRIG MODE ○
AUTO - 1
TIME OFFSET
0 ms
DIS FST DT
+ 5.00 V
INVERT OFF
CHAN Lx

Acquire data.

Check external sensing gain

If you see something like the following the gain of your external sensing equipment is probably to high.


Laryngograph Waveform Display
0 ms
10
20
30
40
50
7.8s
Help
A
Acquire
Zoom
Pan
Cursor
Load
Save
Play
Offset
Print
Set
Quit

CHAN Sp
INVERT OFF
+ 5.00 V
SAMPLE RATE
10 kHz
TRIG MODE ○
AUTO - 1
TIME OFFSET
0 ms
DIS FST DT
+ 5.00 V
INVERT OFF
CHAN Lx

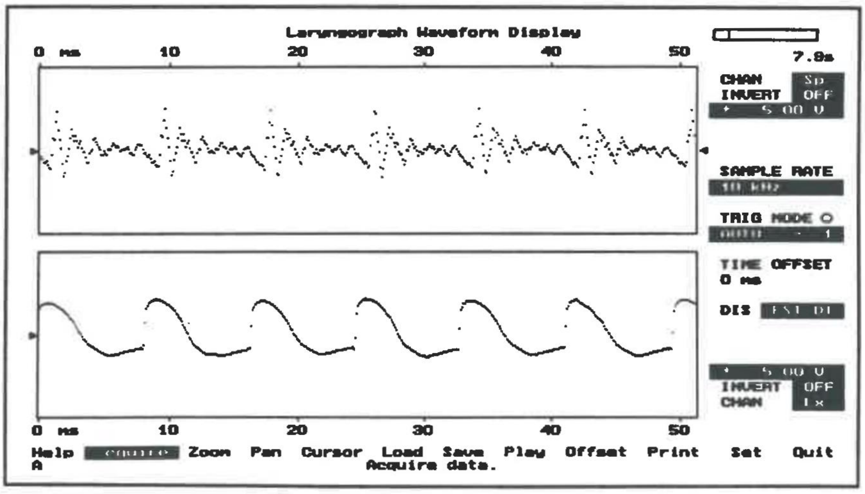
Acquire data.

SHORT time base is normally the best display mode for checking the signal inputs and adjusting levels and settings because it responds instantly and does not require you to press `<Enter>` when the memory has filled as is the case with the LONG time base where the trace writes from left to right in real time until the memory is full and the trace is then frozen.

Setting levels

When setting the levels on the external equipment it is best to have the screen sensitivity settings at +/- 5v. The principle is the same as that in making a good tape recording: record the largest signal possible without distortion. Viewing with the +/- 5v sensitivity will help you do this because +/- 5v are the maximum signal levels which can be recorded without distortion. If, on this range the signal is "clipped" at the top or bottom then that is how the signal has been captured and nothing you do later will be able to redeem it. If a signal appears very small at this sensitivity, it is immediately obvious that it is desirable to increase the amplitude of the input. Whilst it is possible, subsequently, to increase the sensitivity to view small signals it is still desirable to record them at the maximum possible level.

All this being said, setting levels will involve a degree of compromise. The speech waveform in particular is subject to large variations in dynamic range, it will vary: from person to person; with the same person over time; and with microphone placement. Whenever possible fix the microphone position e.g. clip to the shirt or electrode lead, then adjust the gain on your external sensing equipment to achieve the best signal without clipping on the +/- 5v range when the loudest expected speech occurs. This will probably mean that most of the time the waveforms will fill the middle half of the windows as shown below.



Laryngograph Waveform Display

7.9s

CHAN Sp
INVERT OFF
+ 5.00 V

SAMPLE RATE
10 kHz

TRIG MODE ○
[illegible] - 1

TIME OFFSET
0 ms

DIS FST DI

+ 5.00 V
INVERT OFF
CHAN Lx

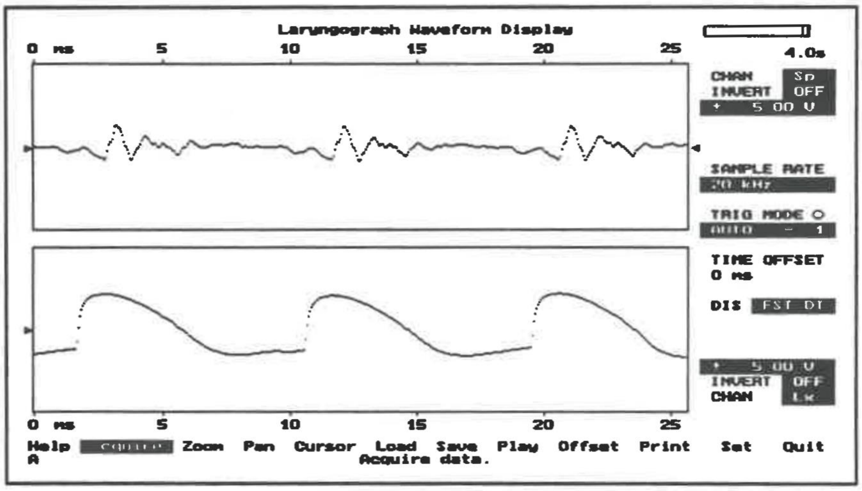
Acquire data.

Changing the sample rate

Setting the sample rate

Whilst acquiring waveforms pressing < will decrease, and pressing > will increase the sample rate.

Press >
Notice that the following settings change: the sample rate to 20KHz, the time base to 25 mS, and the memory indicator to 4 seconds.



Laryngograph Waveform Display

CHAN Sp
INVERT OFF
+ 5.00 V
SAMPLE RATE 20 KHz
TRIG MODE ○ AUTO - 1
TIME OFFSET 0 ms
DIS FST DT
+ 5.00 V
INVERT OFF
CHAN Lx

Acquire data.

Which sample rate should I use?

Lower sample rates allow you to store larger amounts of waveform but with lower time resolution and limited frequency response.

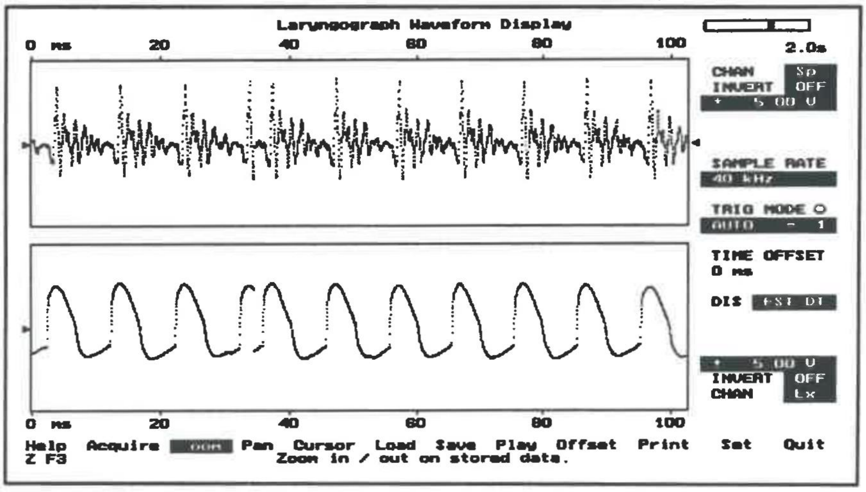
The general rule is that the sample rate should be at least twice that of the maximum frequency components you wish to sample. By frequency components we include not just the fundamental frequency but all the harmonics or multiples of the fundamental which are to be found in a spectrally rich signal such as speech, and indeed in the Lx waveforms. In fact the analogue to digital converters on the interface board will automatically filter out all frequencies above that of half the sample rate to avoid a form of distortion (aliasing) occurring. This means that at 10 KHz sample rate no frequencies above 5 KHz will be represented in the waveforms.

The sample rate should be set in relation to your research or monitoring requirements before you begin data collection and should be borne in mind when making interpretations and carrying out further processing on waveforms.

For general therapy work a 10 KHz sample rate giving a frequency limit of up to 5 KHz is likely to be adequate. A 20 KHz sample rate will give a bandwidth up to 10KHz and 40 KHz

Sample rate limit on some PC's

will capture at up to 20 KHz which is hi-fi quality, capturing everything in the audio band. Whilst the PCLX interface card is capable of supplying up to 4 channels at 40 KHz sample rate, not all PCs can deal with this. If your PC is not able to handle a fast sample rate this will be clear in the frozen display e.g.


Laryngograph Waveform Display
0 ms
20
40
60
80
100
2.0s
Help
Acquire
Zoom
Pan
Cursor
Load
Save
Play
Offset
Print
Set
Quit
Z F3

CHAN Sp
INVERT OFF
+ 5.00 V
SAMPLE RATE 40 kHz
TRIG MODE AUTO - 1
TIME OFFSET 0 ms
DIS FST DT
+ 5.00 V
INVERT OFF
CHAN Lx

Zoom in / out on stored data.

Capturing a waveform

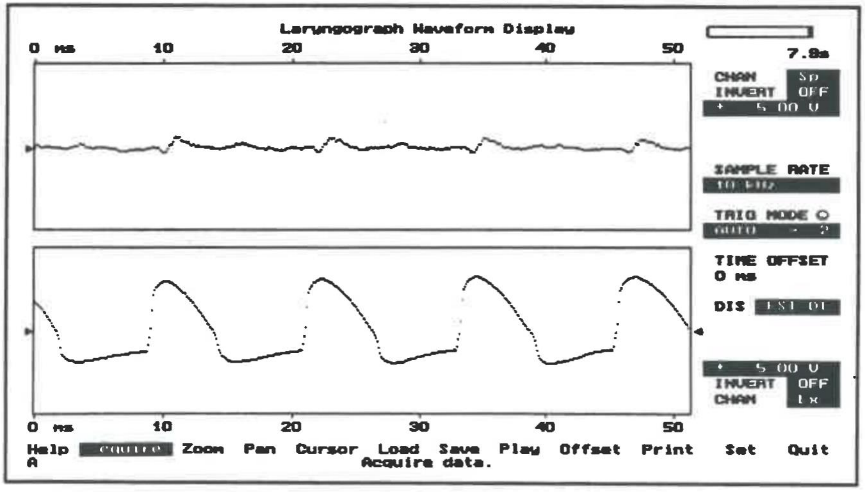
Capturing a waveform.

Highlight Acquire
Press **<Enter>** to begin acquisition
Check you are in SHORT time base mode.
Set levels and check sample is rate set to 10KHz and sensitivity to +/- 5v.

Count slowly from one to ten

Press **<Enter>** as you reach ten.

Your display will then look something like the following.

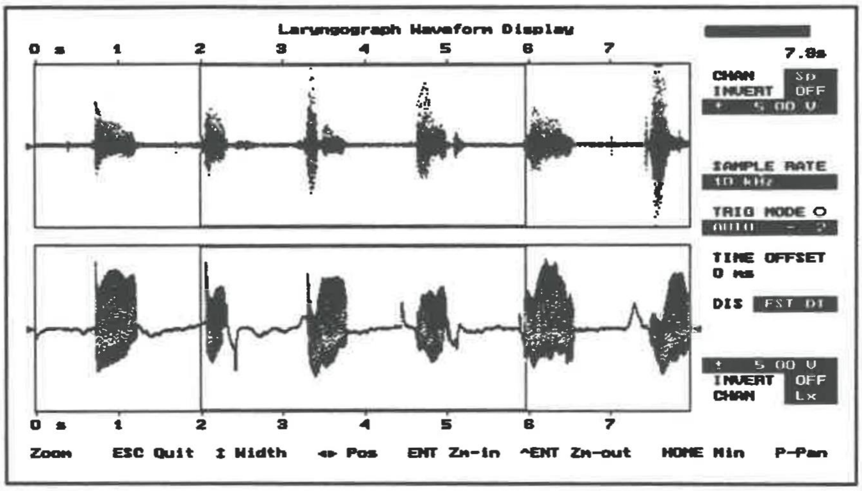

Laryngograph Waveform Display
0 ms
10
20
30
40
50
7.8s
Help
Acquire
Zoom
Pan
Cursor
Load
Save
Play
Offset
Print
Set
Quit
A

CHAN Sp
INVERT OFF
+ 5.00 V
SAMPLE RATE 10 kHz
TRIG MODE AUTO - 2
TIME OFFSET 0 ms
DIS FST DT
+ 5.00 V
INVERT OFF
CHAN Lx

Acquire data.

The indicator in the top right hand corner will change from a clock to a bar, the length of which represents the whole section of memory filled - between 6 and 8 seconds. To view the whole of the memory press **<Z>**, to enter ZOOM and **<HOME>**, to zoom out to the maximum extent. It will take several seconds to redraw the screen at this time base; the display will be like that of the LONG time base.

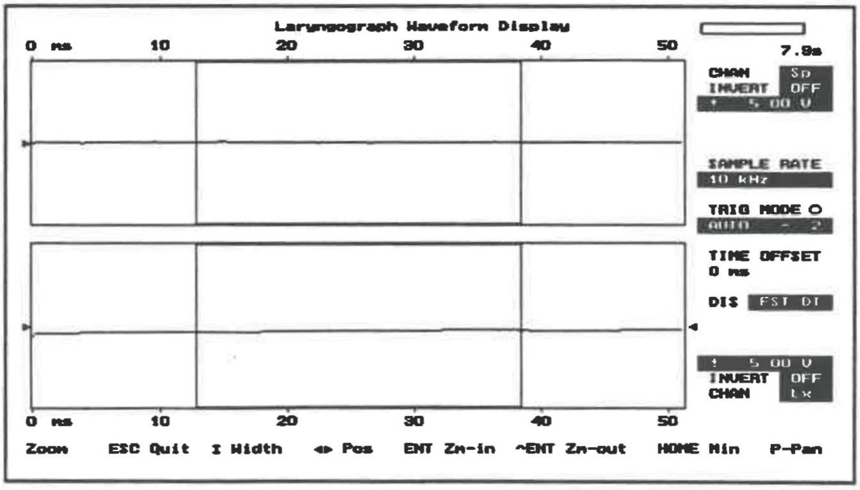
Zoom Out
***<Home>** key*


Laryngograph Waveform Display
0 s
1
2
3
4
5
6
7
7.8s
Zoom
ESC Quit
↕ Width
◂▸ Pos
ENT Zn-in
^ENT Zn-out
HOME Min
P-Pan

CHAN Sp
INVERT OFF
± 5.00 V
SAMPLE RATE
10 kHz
TRIG MODE O
AUTO - 2
TIME OFFSET
0 ms
DIS FST DI
± 5.00 V
INVERT OFF
CHAN Lx

To reverse the process and zoom in to the first 50 mS press <End>. You don't always find something interesting, but you can use the ZOOM and PAN options dealt with in familiarisation.

Zoom In
***<End>** key*


Laryngograph Waveform Display
0 ms
10
20
30
40
50
7.8s
Zoom
ESC Quit
↕ Width
◂▸ Pos
ENT Zn-in
^ENT Zn-out
HOME Min
P-Pan

CHAN Sp
INVERT OFF
± 5.00 V
SAMPLE RATE
10 kHz
TRIG MODE O
AUTO - 2
TIME OFFSET
0 ms
DIS FST DI
± 5.00 V
INVERT OFF
CHAN Lx

The SHORT and LONG of it all.

SHORT is a continuous, instantaneous, cycle by cycle view of a 50mS detailed section of waveform. To freeze the waveform you must press **<Enter>** which stops sampling, whilst retaining a full memories worth of waveform of which only the last 50mS is displayed.

LONG is a real time sweep of several seconds duration in which a memory's worth of waveform is drawn from left to right across the screen and then frozen. Although this is not a true intensity display the compressed view of the speech waveform in time produces a display similar to the peak envelope and as such it may be useful not only as a way of identifying individual sections of speech but also as an indication of the loudness.

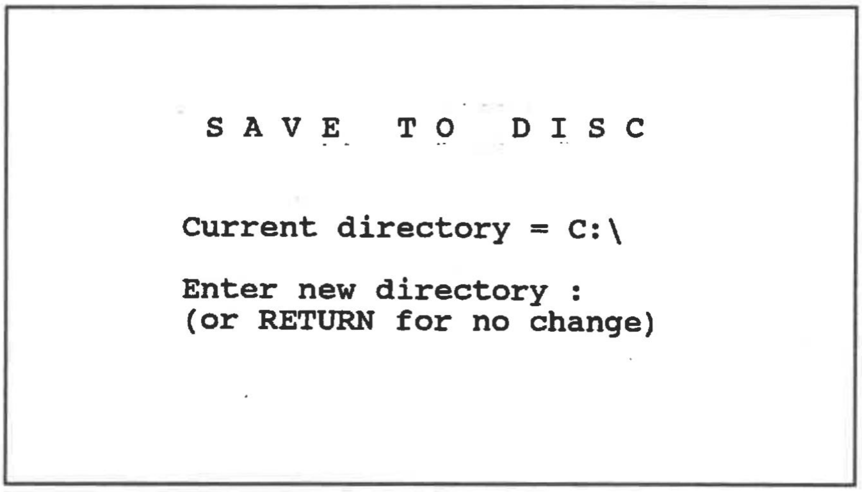
Changing the viewing mode does not change the way data is stored; once the display is frozen you can zoom in and out to view all or part of the waveform and carry out all the manipulations and measurements described in the Familiarisation section.

Save

One feature not covered so far is that you may wish to save your waveform.

Highlight Save
Press **<Enter>**

You have now entered the Save sub menu:



```
SAVE TO DISC

Current directory = C:\

Enter new directory :
(or RETURN for no change)
```

Type in **<Lxdata>** to set the directory.
You will be asked whether you wish to save the whole file or the current screenful only. In this case answer **<N>** to save the whole file.

Type in a name for your file, and as many other details as you wish e.g. operator, subject and any helpful comments for later use.

<Enter> will save the data. The file can be read back into the program in the same way as was done in the example in the familiarisation section.

You have now covered most of the operations you will need and you have the means to explore other options offered on the on screen information line.

There is more information in the reference section.

PCpitch Acquisition

Requirement

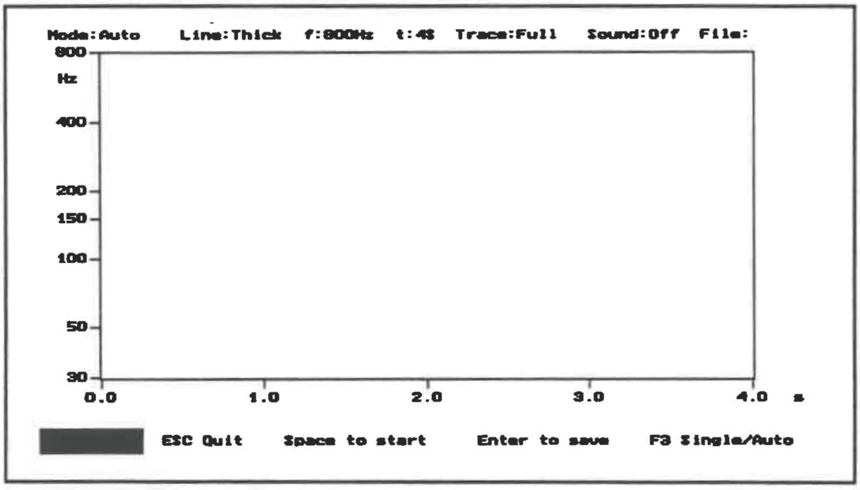
As given for PCwave on Page 2.21

To enter the main menu,
Type **CD PCLX** **<Enter>**
PCLX **<Enter>**

then select PCpitch.

From the PCpitch main menu and display screen:
highlight Acquire and press **<Enter>**

You have now entered the Acquire sub menu.

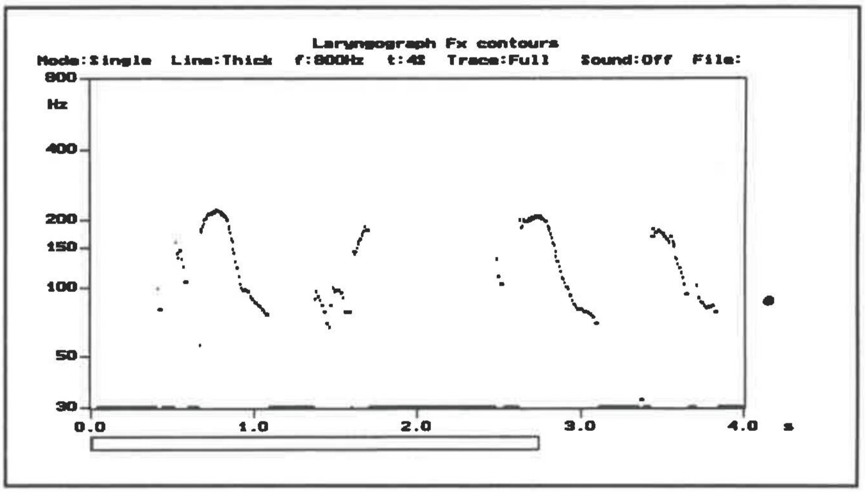


```
Mode:Auto   Line:Thick  f:800Hz  t:4S  Trace:Full   Sound:Off  File:
```

Notice that the main menu line has been replaced by an information line which gives the immediately available options.

Use <F> to change Single/Auto

Notice that MODE is set to AUTO
Press**<F3>**
Mode is now set to single.
Press **<Space>**
a line begins to trace along the bottom of the screen from left to right, and as you phonate rises and falls with your voice fundamental frequency and stops when the trace reaches the right hand side.
The following trace shows a contrastive stress pattern for a male speaker saying "It's easy isn't it", first as a question then as a statement.



Laryngograph Fx contours

Mode:Single Line:Thick f:800Hz t:4S Trace:Full Sound:Off File:

Check:

Electrodes

Live

Output

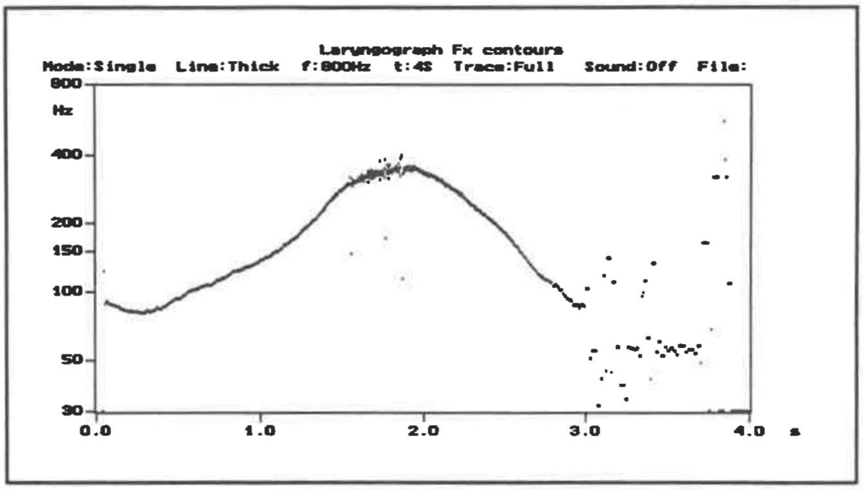
If you do not achieve satisfactory results you should check the following:
: Electrode placement (Use PCwave if necessary to directly monitor Lx).
: LxProcessor input switch is to "Live"
: Output is switched to Lx (You can use Sp but in this case you must position the microphone)

You may need to adjust the gain on the external sensing equipment.
Press **<F3>** again to set the MODE to Auto.
Press **<Space>** to start.
Now when the trace reaches the right hand side the screen clears and begins again. At the same time the memory bar at the bottom of the screen indicates that the memory is filling up.

Gain

Setting the gain

Assuming you have fixed the electrodes properly you can start by turning the Lx gain knob fully off (counter clockwise), make a sustained "Ah" sound at normal pitch and turn the gain knob slowly clockwise until a clean trace of the fundamental frequency appears.
Now try the following:
a low note, a high note, some falsetto and some creak.
Alternatively you may like to try a sweep from low to high and back down again, ending with creak.
The following figure show such a trace for a male speaker:



```
Laryngograph Fx contours
Mode:Single  Line:Thick  f:800Hz  t:4S  Trace:Full   Sound:Off  File:
```

Check that the trace corresponds to your auditory judgement.

Setting the gain

Setting the gain is important. If the gain is set such that a particular sort of voicing does not show on the Fx contour then it will not show in the analysis. You must set the gain to achieve the best match between your auditory judgement and what you see on screen. These programs are designed to help focus on fundamental frequency and to provide quantitative support for informed interpretation, but the responsibility for the accuracy of the data input rests with the operator.

Electrode position

Electrode placement can limit the accuracy with which fundamental frequency can be followed. For example, it is quite common when using falsetto for the larynx to elevate and partially come out of contact with the electrodes thereby reducing the amplitude of the Lx waveform, sometime to the extent that the signal is treated as unvoiced. This may possibly be corrected by placing the electrodes slightly higher on the larynx so that it can better follow the movement, and/or by increasing the gain slightly. In some circumstances e.g. in normal speech, this may not matter, but it is advisable to be aware of the limits in any situation.

Single vs Auto

In SINGLE mode the screen freezes at the end of a trace and pressing **<space>** will clear the screen and start a new trace. This mode may be quite useful for interactive work and demonstrations where a single screen full is all that is required.

AUTO is designed primarily as a means of viewing and acquiring long samples of data for analysis e.g. readings of standard texts. There are some features built in to stop accidental data loss.

<Enter>

When you press **<Enter>** to save data you are taken directly to the SAVE menu to give you a chance to immediately save your data. If you do not wish to save your data at this point **<Esc>**

will take you to the main menu. If you try to acquire new data without first saving the data in memory you will be warned that the existing data will be lost.
An alternative to pressing **<Enter>** in auto mode is to press **<Esc>** this will freeze the display, and sets you within acquire mode waiting for **<space>** to start another trace. In this case there will be no warning about data loss. If you wish to save a trace which was frozen using the **<Esc>** key you can do so by pressing **<Esc>** again to take you to the main menu, then selecting SAVE in the normal way.

Save to disc

Saving data to disc

Whether you have selected the SAVE option or been taken there following acquisition the procedure is the same.

The current directory is listed on the top line and you have the option of entering a new directory on the next line. In the examples in the familiarisation section we used Txdata to store PCpitch files.

Type Txdata **<Enter>**
You will now be given a chance to give your file a name, and to add some further information such as subject, operator, and a description. Typing in your own information will overwrite the example text. Pressing **<F10>** saves the file to disc. The date and time are added automatically.

If you wish to set up your own directory structure you must first create them within DOS (MD Directoryname - see DOS manual for guidance), because PCLX cannot make directories. Once they have been created you can then change to them within PCLX.

For example, to store data (both Lx and Tx under speaker name) you would, before running PCLX, make the directory "speakername" as a subdirectory under PCLX.

From the DOS prompt:
CD PCLX to enter PCLX directory
MD speakername to make directory speakername

You can now run PCLX as usual
PCLX **<Enter>**

and change to speakername directory whenever you wish;
the full path name on a system set up as described in this manual will be:
C:\PCLX\speakername

Options

Options

All the screen display options explained in the familiarisation section are available on the top line. You can move freely between the Fx display and the analysis menu and display although any interpretation must be based on a knowledge of the significance of the number of samples.

Target

Target displays

Highlight TARGET **<Enter>**

The screen now consists of two separate Fx windows, an upper one and lower one. In fact the memory is also partitioned and you can have two quite distinct sets of data, ie. you have the possibility of acquiring, viewing and analysing two separate sets of Tx data. Only one window is active at a particular time: the active window is indicated by the illumination of the small green circle to right of the window. As usual, the window is switched using the **<TAB>** key.

<Tab>
to switch

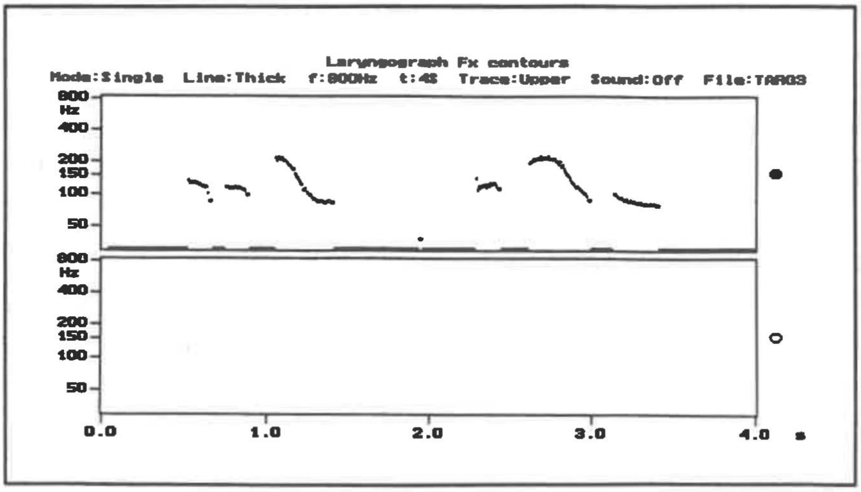
The procedures for acquiring data into one of the target displays are the same as for acquiring into full screen.

Acquire

With the top screen active highlight ACQUIRE **<Enter>**

The upper screen will now begin to display the trace as you voice.

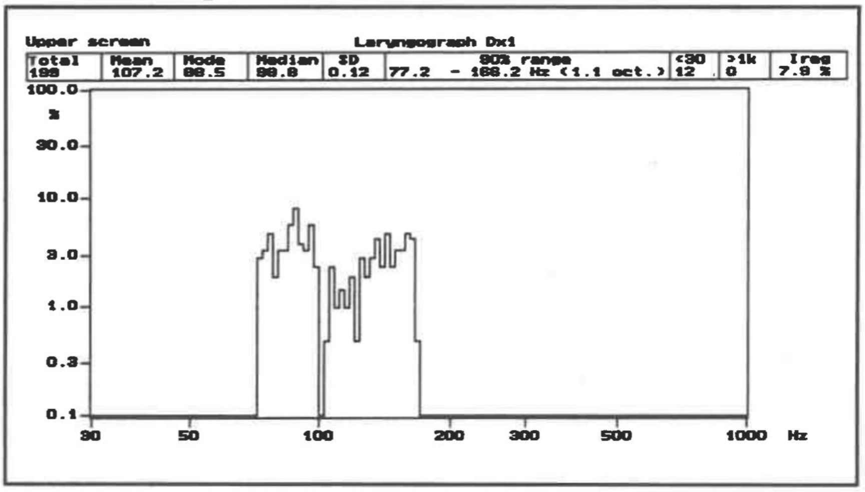
The following is an example of a male speaker saying "I can see" with the emphasis first on "see" and then on "can".



Mode:Single Line:Thick f:800Hz t:4S Trace:Upper Sound:Off File:TARG3

Analyse

Pressing **<TAB>** makes the lower screen active and you can now acquire into this screen.
Highlighting ANALYSE **<Enter>** will take you to the analysis menu and display for the window that is active. The following screen shows the first order Dx for the examples just given. It also demonstrates the kind of analysis you get from a small number of samples.



Upper screen Laryngograph Dx1

Total	Mean	Mode	Median	SD	80% range	<30	>1k	Ireg
198	107.2	88.5	98.8	0.12	77.2 - 168.2 Hz (1.1 oct.)	12	0	7.9 %

Switching Target/Full

Switching between TARGET and Full screen displays.

With the target display the memory is divided in two, therefore, when switching between Full and Target some decisions are necessary on the memory organisation: what data is to go where and what if anything is to be erased. The principles we have adopted are as follows: When switching between Full and Target the data is transferred to the section of memory corresponding to the upper screen. If this section of memory is not sufficient to store the full screen data a warning will be made. This is, however, unlikely because of the large amount of memory available. When you transfer from Target to Full, the data from the upper screen is loaded into the full screen memory and the lower screen memory is effectively erased. As is the case when loading from disc into a window different from that in which the data was saved, transferring from full to target may mean that you will have to PLAY before the trace is visible.

Saving data

Save

When you save to disc only the data from the active window is saved. When you load from disc, the data is loaded into the active window. If the active window on loading is the same as that when the file was saved the Fx contour on screen at the time will also be immediately displayed. If the active window on loading is not the same as when the file was loaded the data will be loaded into memory but will not be displayed until PLAY has been selected.

Applications

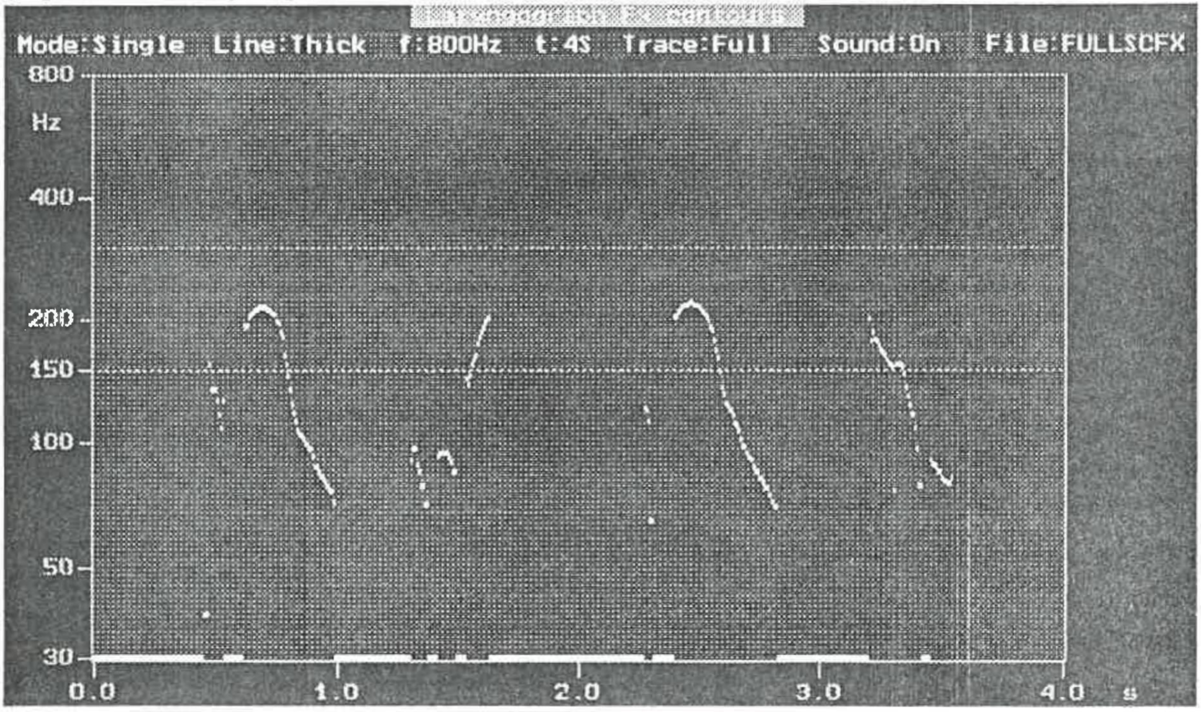
Overview	Not ready	3.2.
Working with visual feedback on perception and production. Some general principles of immediate and delayed feedback.		
The EPI programme	-	3.3.
Working with a postlingually, profoundly deaf adult population.		
Voice	Not ready	3.4.
Foreign language teaching	Not ready	3.5.

Grabing PCLX files into word perfect

1. From the DOS prompt change to the word perfect directory. Type GRAB and <Enter>.
2. Load PCLX, select PCpitch or PCwave as you like, acquire or load in data. When you have the image you wish to capture press the "Grab Hot Key sequence" (Alt-Shift-F9).

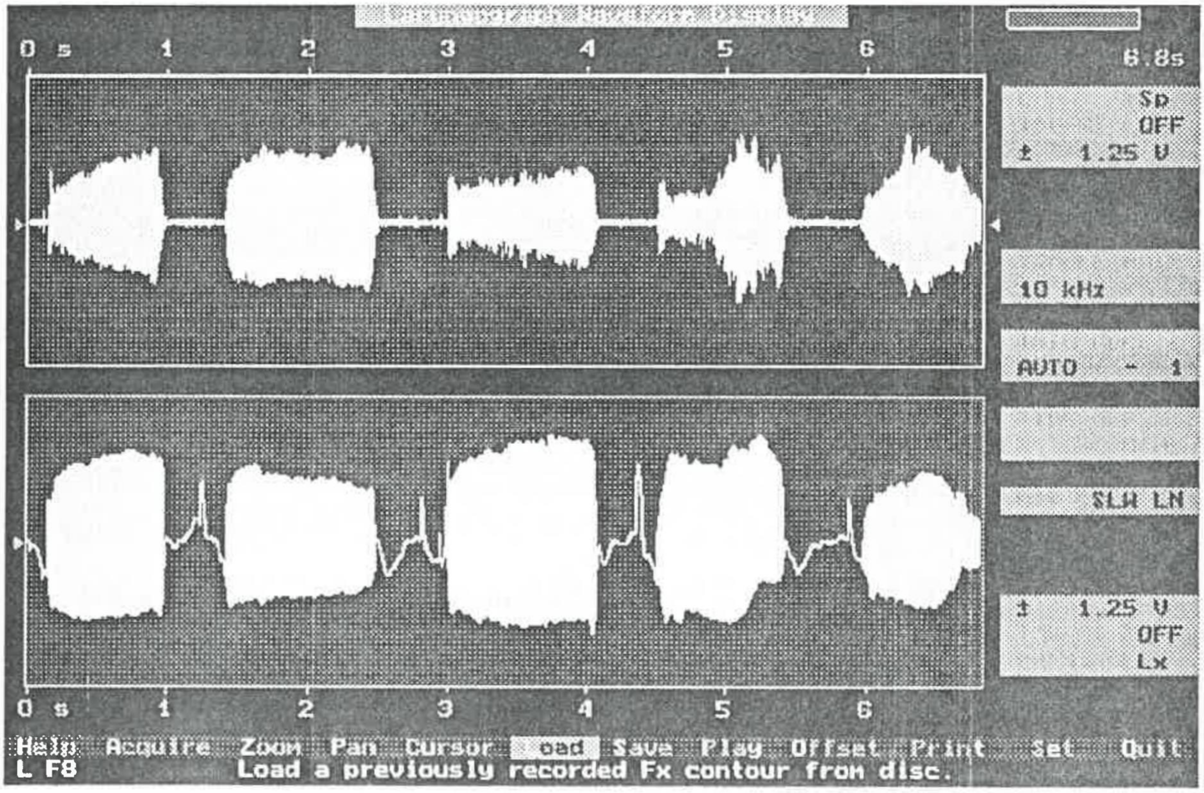
If Grab can capture the screen you will hear two short beeps. Use the arrow keys to position the box and Shift and arrow keys to increase the size. Press <Enter> when ready. Grab saves the screen as GRAB.WPG into the current directory.

3. To display within a word perfect file you have to create a graphics box into which the file is loaded. From within a wordperfect document Alt F9 selects graphics mode, choose "User box" from the menu and fill in the file name (give complete path to PCLX directory in which you stored the Grab file), you can size the box as you wish but "Auto" may be the best to start with, also it may be less confusing if the position is set to the Left. You will not be able to see the graphics file until you print or Preview (Shift F7, option 6).



Mode:Single Line:Thick f:800Hz t:4S Trace:Full Sound:On File:FULLSCFX

800
Hz
400
200
150
100
50
30
0.0
1.0
2.0
3.0
4.0 s



0 s
1
2
3
4
5
6
6.8s
Sp
OFF
± 1.25 V
10 kHz
AUTO - 1
SLW LN
± 1.25 V
OFF
Lx
Help
Acquire
Zoom
Pan
Cursor
oad
Save
Play
Offset
Print
Set
Quit
L F8

Load a previously recorded Fx contour from disc.

PCpitch Fundamental frequency measurement and resolution.

PCpitch derives measures of fundamental frequency by measuring the time between pulses supplied to the Tx input of the PCLX interface card. These Tx pulses must be supplied by external fundamental period marking circuits. The PCLX card can measure the interval between the negative going edge of such pulses to approximately 2 micro seconds accuracy. With the Laryngograph Processor(PC) and (PCLX) the Tx pulses can be derived either from the speech waveform or the Laryngograph waveform.

Laryngograph period marking.

This circuit produces a negative going pulse when 1. voicing has been detected by a voicing detection circuit and 2. when a positive going edge of sufficient relative amplitude has been detected. The output is thus a train of pulses with the negative edge locked to the positive edge of peaks in the Laryngograph waveform when voicing is taking place.

Speech waveform period marking

The operation of this circuit depends on the fact that the pressure waveform for voiced speech, when undistorted in phase, has one major peak per period. The device aims to isolate these major peaks and to output one pulse for each, thus defining the fundamental period. If the input is voiceless speech or silence, additional preprocessing stages ensure that the peak picking stages of the device do not receive any peaks of sufficient amplitude to be detected.

Tx Pulse period measurement

The Tx pulses from the external equipment are taken to an interrupt request (IRQ) input on the PCLX acquisition card. A digital monostable responds only to -ve going edges of any mark/space ratio. The IRQ is input to the TMS320C25. Internal software reads a 10 or 12.5 MHz clock (According to whether the master oscillator is set to 40 or 50 MHz), and times the interval since the last Tx pulse. The result is divided by 10 (or 12.5 for 50 MHz boards) to give the result in micro-seconds and this value is passed to the PC. Long periods of several minutes can be measured and short periods down to 250 micro-seconds. Periods shorter than 250 micro-seconds are eliminated. The accuracy of the period measurement will normally be to 1 micro-second, however a worst case interrupt latency of 20 machine cycles could result in a worst case accuracy of 2 micro-seconds. PCpitch files are called Tx files because it is these Tx values that are saved.

Fundamental frequency display resolution

A lookup table is used to convert the Tx period measured in microseconds to the logarithm of the reciprocal to give a value of frequency on a logarithmic scale. The frequency is displayed on a screen of 256 pixels vertically. A timer moves the plotting point from one column of pixels to the next at an interval equal to the number of seconds being displayed divided by the horizontal resolution of 512 pixels, in the case of a 4 second display this occurs every 7.8 milli seconds (128 Hz). Whilst on a particular column, everytime a Tx value is converted to a Log frequency value it is plotted in that column. This means that for frequencies greater than 128 Hz it is possible that more than one point will be plotted in each column. This will lead to the creation of a broader trace.

A delay of 5 or 6 pixels of time is incorporated in the plotting procedure. If a Tx pulse has not been received in this time, silence is assumed and the trace set to the baseline.

Distributions of fundamental frequency.

These displays consist of histograms with the horizontal axis divided into 128 evenly spaced divisions based on a logarithmic scale between 30Hz and 1000Hz, these are referred to as bins. The measured frequencies are sorted into these bins in a manner dependant on the distribution chosen.

When the distributions are plotted the contents of each bin is displayed as a probability percentage of the overall number of samples in the first order distribution (this is done so that cross comparison is meaningful). The calculated statistics are also displayed along with the distribution file.

Dx1: First order distribution.

The first order distribution is obtained by sorting every frequency (from the measured Tx period) into the appropriate frequency bin and incrementing the number referring to the total contents of this bin. If the frequency is too large it is noted in the > 1000Hz column; if it is too small it is noted in the < 30Hz column.

The centre frequency of bin n is given by:

$$10^{\left\{\left(\frac{\log_{10}(1000) - \log_{10}(30)}{128} * (n + 0.5)\right) + \log_{10}(30)\right\}}$$

Dx2: Second order distribution.

The second order Dx distribution is obtained by only incrementing a bin total for an Fx value which falls in the same bin as the immediately preceding value. If the Fx value does not fall in the same bin as the previous one it is discarded. This processing method has the effect of removing irregularity and only taking into account sections of Fx which are constant or changing smoothly and relatively slowly.

Cx: Cross plots of fundamental frequency.

The Cx display consists of a horizontal and vertical axis both displaying frequency on a logarithmic scale between 30Hz and 1000Hz and divided into 64 equally spaced divisions. This gives a two dimensional matrix of 4096 elements, these are referred to as bins in a similar fashion to the Dx bins.

The Cx display is built up by calculating the frequency of the first Tx value in the data sample and using this as the horizontal coordinate for the relevant bin. The frequency of the second Tx value is then calculated and used as a vertical coordinate, thus pinpointing the specific bin in the matrix which is then incremented. The second calculated coordinate is then used as the first or horizontal coordinate and another Tx value taken from the data sample as the second or vertical coordinate. In this way the matrix is filled up until the whole data sample has been processed and the characteristic scatter pattern formed.

If the coordinate pair do not fall within the matrix then no location is incremented and Cx proceeds to process the next Fx value.

When the Cx display is plotted on the screen the number of samples occurring in any one matrix bin is shown on a logarithmic intensity level of 16 levels. This scale is referenced to the matrix bin containing the most number of Fx samples, which is shown as the most intense location.

The lowest level of the intensity scale is "flexible", showing all the matrix bins which contain at least two samples. This feature is included to eliminate spurious "noise" shown in single samples, but also to give a realistic display of the scatter of the speaker's fundamental frequency.

Mode:

The mode is defined as the centre frequency of the bin containing the highest number of samples.

Mean:

The mean is found by summing the product of each bin number (from 1 to 128) and the number of samples it contains, dividing this sum by the total number of samples and taking the centre frequency of the corresponding bin.

Median:

The median is given as the centre frequency of the distribution bin which contains the middle point of the display (i.e. 50% of samples fall to the left and 50% to the right of this point).

The standard deviation in terms of *bin number* is given by the following formulae:

$$\sqrt{\frac{\sum_{1}^{128} (\text{bin } [i] * (i - \text{mean})^2)}{\text{total}}}$$

Where: bin [i] is the number of samples in bin number i
mean is the bin number containing the mean
total is the total number samples

To get the standard deviation in Log Hz, multiply by:

$$\frac{\log_{10} (1000) - \log_{10} (30)}{128}$$

The 80% range

The lower value is the centre frequency of the bin which has 90% of the samples above it and the uppper value is the centre frequency of the bin which has 10% of the samples above it. The frequency range is also presented in terms of octaves.

The 90% range

The lower value is the centre frequency of the bin which has 95% of the samples above it and the uppper value is the centre frequency of the bin which has 5% of the samples above it. The frequency range is also presented in terms of octaves.

Irregularity

Irregularity is here used to denote irregularity of vocal fold vibration which occurs throughout the fundamental frequency range rather than "creak", the subset of irregular vibration, that falls only in the low frequencies.

This measure is based on taking a three bin width diagonal of the Cx plot as representing regular voice, counting all fundamental frequency pairs outside this central band and presenting as a percentage of the total number of fundamental frequency pairs.

For these analyses the bin width, expressed as a percentage of centre frequency, is 5.48%. A three bin width diagonal allows a one bin deviation either side of the central diagonal - a maximum of almost two bins to be counted as regular. This is equivalent to a maximum cycle to cycle variation of 10.96%. In musical terms, the Cx bin sizes are slightly smaller than a semitone (our range of 64 bins represents 58 semitones) so as an approximation, cycle by cycle variations of up to almost two semitones are counted as regular.

List of Cx bin values and widths

```
Edge freq      Bin   centre freq     bin width
---------------------------------------------------------
   30.00Hz
   31.69Hz      1     30.83Hz        1.69Hz  (5.48%)
   33.47Hz      2     32.57Hz        1.78Hz  (5.48%)
   35.36Hz      3     34.40Hz        1.89Hz  (5.48%)
   37.35Hz      4     36.34Hz        1.99Hz  (5.48%)
   39.45Hz      5     38.39Hz        2.10Hz  (5.48%)
   41.68Hz      6     40.55Hz        2.22Hz  (5.48%)
   44.02Hz      7     42.83Hz        2.35Hz  (5.48%)
   46.50Hz      8     45.25Hz        2.48Hz  (5.48%)
   49.12Hz      9     47.79Hz        2.62Hz  (5.48%)
   51.89Hz     10     50.49Hz        2.77Hz  (5.48%)
   54.81Hz     11     53.33Hz        2.92Hz  (5.48%)
   57.90Hz     12     56.33Hz        3.09Hz  (5.48%)
   61.16Hz     13     59.51Hz        3.26Hz  (5.48%)
   64.60Hz     14     62.86Hz        3.44Hz  (5.48%)
   68.24Hz     15     66.40Hz        3.64Hz  (5.48%)
   72.08Hz     16     70.14Hz        3.84Hz  (5.48%)
   76.14Hz     17     74.09Hz        4.06Hz  (5.48%)
   80.43Hz     18     78.26Hz        4.29Hz  (5.48%)
   84.96Hz     19     82.67Hz        4.53Hz  (5.48%)
   89.75Hz     20     87.32Hz        4.78Hz  (5.48%)
   94.80Hz     21     92.24Hz        5.05Hz  (5.48%)
  100.14Hz     22     97.43Hz        5.34Hz  (5.48%)
  105.78Hz     23    102.92Hz        5.64Hz  (5.48%)
  111.74Hz     24    108.72Hz        5.96Hz  (5.48%)
  118.03Hz     25    114.84Hz        6.29Hz  (5.48%)
  124.68Hz     26    121.31Hz        6.65Hz  (5.48%)
  131.70Hz     27    128.14Hz        7.02Hz  (5.48%)
  139.12Hz     28    135.36Hz        7.42Hz  (5.48%)
  146.95Hz     29    142.98Hz        7.83Hz  (5.48%)
  155.23Hz     30    151.03Hz        8.28Hz  (5.48%)
  163.97Hz     31    159.54Hz        8.74Hz  (5.48%)
  173.21Hz     32    168.52Hz        9.23Hz  (5.48%)
  182.96Hz     33    178.02Hz        9.75Hz  (5.48%)
  193.26Hz     34    188.04Hz       10.30Hz  (5.48%)
  204.15Hz     35    198.63Hz       10.88Hz  (5.48%)
  215.65Hz     36    209.82Hz       11.50Hz  (5.48%)
  227.79Hz     37    221.63Hz       12.14Hz  (5.48%)
  240.62Hz     38    234.12Hz       12.83Hz  (5.48%)
  254.17Hz     39    247.30Hz       13.55Hz  (5.48%)
  268.49Hz     40    261.23Hz       14.31Hz  (5.48%)
  283.61Hz     41    275.94Hz       15.12Hz  (5.48%)
  299.58Hz     42    291.48Hz       15.97Hz  (5.48%)
  316.45Hz     43    307.90Hz       16.87Hz  (5.48%)
  334.27Hz     44    325.24Hz       17.82Hz  (5.48%)
  353.10Hz     45    343.56Hz       18.83Hz  (5.48%)
  372.98Hz     46    362.90Hz       19.89Hz  (5.48%)
  393.99Hz     47    383.34Hz       21.01Hz  (5.48%)
  416.18Hz     48    404.93Hz       22.19Hz  (5.48%)
  439.62Hz     49    427.74Hz       23.44Hz  (5.48%)
  464.38Hz     50    451.83Hz       24.76Hz  (5.48%)
  490.53Hz     51    477.27Hz       26.15Hz  (5.48%)
  518.16Hz     52    504.15Hz       27.63Hz  (5.48%)
  547.34Hz     53    532.55Hz       29.18Hz  (5.48%)
  578.16Hz     54    562.54Hz       30.83Hz  (5.48%)
  610.72Hz     55    594.22Hz       32.56Hz  (5.48%)
  645.12Hz     56    627.69Hz       34.40Hz  (5.48%)
  681.45Hz     57    663.04Hz       36.33Hz  (5.48%)
  719.83Hz     58    700.38Hz       38.38Hz  (5.48%)
  760.37Hz     59    739.82Hz       40.54Hz  (5.48%)
  803.19Hz     60    781.49Hz       42.82Hz  (5.48%)
  848.43Hz     61    825.50Hz       45.23Hz  (5.48%)
  896.21Hz     62    871.99Hz       47.78Hz  (5.48%)
  946.68Hz     63    921.10Hz       50.47Hz  (5.48%)
 1000.00Hz     64    972.98Hz       53.32Hz  (5.48%)
```

Lx File Structure

Here is the structure of the file header. The total size, as given by

```
sizeof(filehead_t)
```

is 372 bytes.

```
typedef struct {
      char title[7];                /* id string                               */
      int  version;                 /* version number (eg 101 is v1.01)        */
      char board_s_no[10];          /* serial number string from board         */
      char when[26];                /* date & time as returned by ctime()      */
      char ptname[40];              /* patient's name, last name first         */
      char opname[20];              /* operator's name,  ....                  */
      char comment[185];            /* comments (only using 80 chars, but leave
                                       room for more fields later              */
      char filename[13];            /* DOS file name                           */
      char datatype;                /* T=TX, F=FX, 1-4=waveforms, M=mixed      */

            /******* --< end of common data format >--   ******/

      long samplefreq;              /* sample freq used to acquire data */
      int envelope;                 /* Envelope mode on/off             */
      int joindots;                 /* Joined dots on frozen dsiplay    */
      long time_offset;             /* time offset. +ve = B moved forward in
                                       time                             */
      trigctrl_t trigctrl;          /* trigger set-up                   */
      scopectrl_t scopectrl[2];     /* scope set-up                     */
      int window;                   /* current widdow                   */
      int joinedcursors;            /* cursor are locked in two screens */
      curinfo_t cursor[2];          /* cursor positions                 */
      long startpos;                /* relative to first sample         */
      float zoomfactor;             /* number of data pts per pixel     */
      unsigned long datalen;        /* number of data structures to follow/*
} fileheader_t;
```

The various type defines used in the header are as follows:

```
typedef struct {
      int mode;         /* off, auto, man, single      */
      int level;        /* samplevalues                */
      int slope;        /* -1 or +1                    */
      int win;          /* top or bot                  */
      int pretrig;      /* 16 chunks for 25%           */
} trigctrl_t;

typedef struct {
      int chan;         /* off, a, b                   */
      int invert;       /* false, true                 */
      int sensitivity;  /* samplevalues per pixel      */
      int offset;       /* baseline shift              */
} scopectrl_t;

typedef struct {
      int mode;         /* bit 1 = active cursor, bit 2 = on/off */
      int pos[2];
} curinfo_t;
```

The format of the data following the header (for 2 channel data) is given by

```
typedef struct {
      int chan[2];
} adata_t;
```

Tx File Structure

FILESTUC.DOC 1492 bytes, Tue Mar 3 12:44:04 1992

Here is the structure of the TX file header.

```
#define MAXSCREENWIDTH 640     /* maximum screen width                          */

typedef struct {
     char title[7];                  /* id string                              */
     int  version;                   /* version number (eg 101 is v1.01)       */
     char board_s_no[10];            /* serial number string from board        */
     char when[26];                  /* date & time as returned by ctime()     */
     char ptname[40];                /* patient's name, last name first        */
     char opname[20];                /* operator's name,  ....                 */
     char comment[185];              /* comments (only using 80 chars, but leave room for more fields later */
     char filename[13];              /* DOS file name                          */
     char datatype;                  /* T = TX, F = FX curve, W = waveforms, M = mixed      */
     int displaymode;                /* 1 = clear, 2 = refresh, 3 = single     */
     int targetmode;                 /* 0 = Full, 1 = top, 2 = bottom   +4 = target data valid, +8 =  pt data valid *
     int thickorthin;                /* 1 = thick, 2 = thin                    */
     int maxfxfreq;                  /* 400 / 800 Hz max displayed freq        */
     int maxfxtime;                  /* time accross x axis                    */
     int noisyfx;                    /* noise when playing fx contour          */
     int marker1f;                   /* frequency for upper marker             */
     int marker2f;                   /*                 lower                  */
     int markers;                    /* markers on/off flag                    */
     long datalen[2];                /* data length                            */
     int screenvals[2][MAXSCREENWIDTH];      /* screen dumps 0 = target or full, 1 = patient */
} fileheader;
```

The total length of the header is 2892 bytes.

INTERFACE CARD

Installation

The PCLX interface card has been designed to run on all 8 bit PC/XT and 16 bit PC/AT bus interfaces. Running the PCLX program will automatically run some diagnostics programs to check that the board is functioning properly and that there are no conflicts with other boards which may be present. These conflicts may relate to the DMA channels and Interrupt lines or I/O address used. The board is supplied to run on an PC/AT using DMA channel 3 and Interrupt 15 and I/O address Hex 2C0. It is possible to change the DMA, Interrupt lines and I/O address used by PCLX by adjusting the on board jumpers and DIP switches and editing the program configuration file (PCLX.CFG). If you want to change these settings you will find details later in this section.

To install the PCLX interface card you will need to:

- ensure your computer is switched off.

- open the lid

- unscrew one of the blank panels on the back of the computer

- hold the PCLX card in its anti-static bag and momentarily touch some unpainted part of the PC chassis to discharge any static.

- remove the PCLX card from its bag

- push the card firmly into one of the spare 16 bit (i.e. long) sockets on the PC motherboard

- screw down the mounting bracket

- replace the computer lid

- the computer can now be turned on

- run the PCLX program

If everything works O.K. you will not be aware of the diagnostics program; it will run and then take you into PCLX. If some fault is found an error message will appear on screen. In some cases the message will tell you what to do. If it does not you should contact us for advice.
You can run the diagnostics program on its own:
From the PCLX directory type PCLXTEST and press Enter.

Changing the settings on the PCLX Interface.

This is a two step process:

1. Change the settings on the card

2. Change the PCLX configuration file so that the software operates with the new settings.

1. Changing the settings on the card.

You can change the interrupt line, the DMA channel and the board I/O address. The interrupt line and the DMA are changed by moving jumper connectors and the address by setting DIP switches. All these settings are to be found at the bottom of the board above and to the left of the gold plated edge connectors. All are labelled.

a. Changing the Interrupt line
This is labelled IRQ and numbered from 2 through to 15. Simply lift off the jumper and insert by the appropriate number.

b. Changing the DMA channel

This is labelled DMA and numbered in pairs 0, 1, 2, 3. Move the pair of jumper connectors together, two steps at a time, to correspond with the appropriate number.

c. Changing the I/O address

The I/O address is controlled by a bank of eight switches labelled Address bits and numbered, on the board, from 3 through to 9 (MSB). (NOTE: do not confuse the address line number with the DIP switch number, the numbers on the switch itself do not quite correspond e.g. address bit 3 = switch 2). Logic 1 = "OFF".

The I/O address given in the PCLX.CFG file is in Hex. The default setting is Hex 300. This corresponds to logic 1 on address lines 9 (MSB) and 8. Other lines are set to logic zero.

To change the address you will need to convert the required Hex address to binary and set the switches accordingly. There is a program to help you: PCLXTEST -s will show you the switch settings for Hex address

2. Changing the PCLX.CFG file.

You will need a "non document" mode editor. Word perfect can be used provided the "TEXT IN/OUT" (<Ctrl> <f5>) is used both to load and save the file. Wordstar in non document mode can also be used. Xtree also has a suitable editor. The settings are changed simply by deleting the old and typing in the new. For example, to change to DMA channel 0, move the cursor to dma channel, delete 3 and insert 0. Then save the file (in non document mode).

Example of PCLX.CFG file

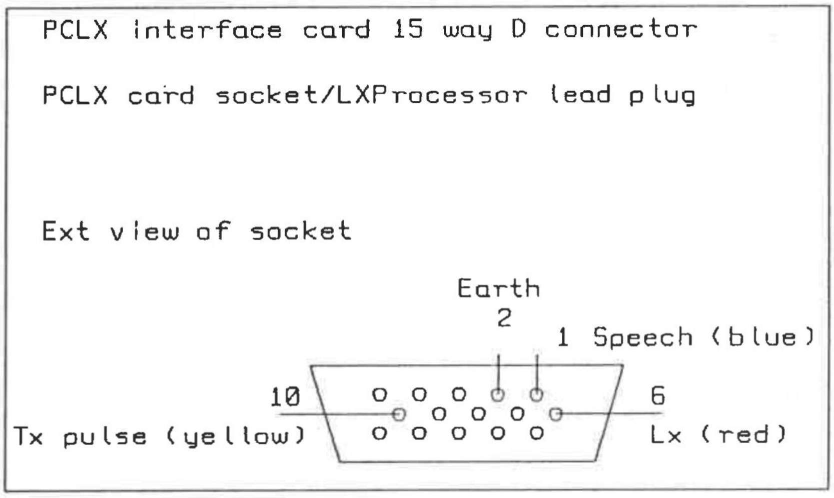
```
; PCLX.CFG
; configuration file for pclx
; lines starting with a semi-colon ';' are ignored

;-------------------------------------------------------------
-----;
; THIS FILE MUST ONLY BE EDITED USING A "NON DOCUMENT" MODE
EDITOR ;
;-------------------------------------------------------------
-----;

;---------------- general software setup
---------------------------
country          uk                  ; uk (french not yet implimented)

;-------------------- pcpitch setup
------------------------------------
maxfreq   800                  ; 400, 800
maxtime          4                   ; 2, 4, 6
displaymode      auto                ; single, auto
line             thick                    ; thick, thin
sound            off                 ; on, off
markers   on                   ; on, off
marker1          100                 ; integer freq for marker1
marker2          200                 ; integer freq for marker2

;-------------------- pcwave setup
------------------------------------
samplefreq       1                   ; 0 = 5k, 1 = 10k, 2 = 20k, 3 = 40k
label-a          Sp                  ; legend for labeling input channel
a
label-b          Lx                  ; legend for labeling input channel
b

;------------------- hardware setup
------------------------------------
graphicstype   detect                    ; detect, herc, ega
pcboard          3                   ; 1 = first proto. 2 = second
proto. 3 = first production
dmachannel       3                   ; 0, 1, 3
interrupt 15                   ; 3, 10, 11, 12, 13, 15
ioaddress 2c0                  ; 3 hex digits eg. 300, 4a0

;------------------- printer setup
------------------------------------
printer          fx                  ; fx, lj
printautocr      no                  ; usually no for lj, yes for fx
; printerinit    27,67,0,11               ; list of decimal values to
setup printer
```

PCLX Interface card: lead wiring details

1. 15 way high density D-type socket

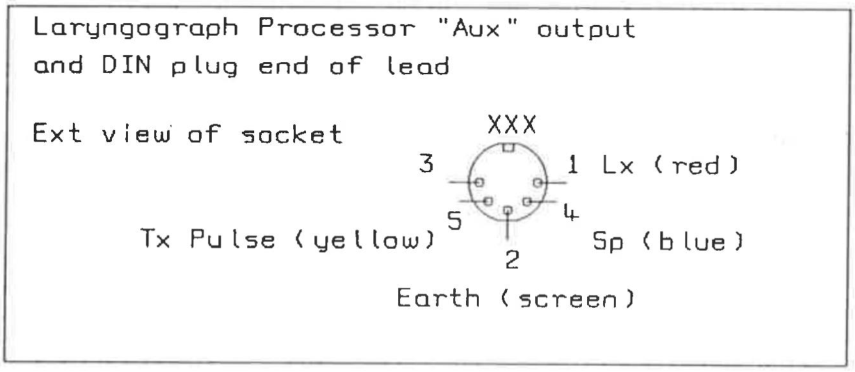
Pin 1	Speech input (Analogue +/- 5 volts) (Blue)
Pin 6	Lx input (Analogue +/- 5 volts) (Red)
Pin 10	Tx pulse (digtal logic levels, timer triggers on -ve edge)(Yellow)
Pin 2	Earth

The colours refer to the insulation on the standard lead supplied.


PCLX interface card 15 way D connector
PCLX card socket/LXProcessor lead plug
Ext view of socket
Earth
2
1 Speech (blue)
10
Tx pulse (yellow)
6
Lx (red)

2. The Din plug at the end of the standard lead is wired to connect to the appropriate signals on the Lx Processor "Aux" output.

Pin 1	Lx (Red)
Pin 4	Sp (blue)
Pin 2	Earth (screen)
Pin 5	Tx pulse (from Lx or Sp dependant on output switch)


Laryngograph Processor "Aux" output
and DIN plug end of lead
Ext view of socket
XXX
3
1 Lx (red)
5
4
Tx Pulse (yellow)
Sp (blue)
2
Earth (screen)

3. The mini jack socket is for headphones (walkman style) to monitor two channel analogue waveform playback.

User Guide

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	LxProcessor (PC)	
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	Mains use	
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	Electrodes	
Recording		8.4
Playback		
Linking to PC		
Knobs and switches	Input	8.5
	Output	
	Gain	

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	Front and back panels	8.8
	Back panel details	8.9
	Tape recorder connection	8.10
Overall layout		
PCB component layout		8.11
Circuit Diagrams and parts lists	Miscellaneous circuits	8.12
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	circuit	
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1. Options

i. Laryngograph Processor (PCLX)

The Laryngograph Processor (PCLX) is an all-in-one portable electro-laryngograph, microphone pre-amplifier, and speech or laryngograph based fundamental frequency ("pitch") extractor.

It links simply to a recorder (e.g. cassette or DAT) for the recording or playback of the Speech (Sp) and Laryngograph (Lx) waveforms and to the PCLX Interface card which can be fitted to any IBM PC compatible for the display, analysis and printout of the speech and Laryngograph waveform and corresponding fundamental frequency.

It is supplied with a small high quality electret microphone to pick up the speech pressure waveform (Sp) and a set of electrodes which, when positioned on the neck on the wings of the thyroid cartilage, detect the small, relatively rapid, variations in the conductance between the electrodes, produced by changes in the nature and area of vocal fold contact during voiced speech.

ii. Laryngograph Processor (PC)

The Laryngograph Processor (PC) is designed as an add on unit for those who already have portable Laryngographs. It is a microphone preamplifier, microphone fundamental frequency ("pitch") extractor and an Lx period marker. Once the Portable Laryngograph output has been connected to the Lx input on the Laryngograph Processor (PC) the system has the same features as the Laryngograph processor (PCLX).

2. Getting going

Switching on

The unit is switched on by the small switch towards the left hand side of the back panel. When the unit is on, the small light at the top right hand side of the front panel will light up. If the battery is sufficiently charged, or if the mains unit is plugged in and switched on, the light will be green. If the mains unit is unplugged and the battery is insufficiently charged the light will be be amber.

Battery indication

A fully charged battery will give approximately thirty hours continuous use before the light changes from green to amber. Once this change occurs there will be approximately 5 hours life remaining, but you are advised to recharge as soon as is possible.

Mains operation

When the mains power supply unit is plugged in the Lx Processor will be driven from the mains and the battery will be simultaneously charging.

Allow 20 hours for complete battery recharge with the Lx Processor switched off.

Microphone
The Microphone plugs into a socket on the left hand side of the front panel and the output level is controlled by the knob beside it. A small green light next to the microphone socket lights up when the microphone detects, for example, voiced speech.

Electrodes
The electrodes plug into the pale blue socket on the right hand side of the front panel and the output level is controlled by the adjacent knob. When the electrodes are on the neck the small green light next to the electrode socket comes on when vocal fold contact occurs. It will stay on during phonation.

Electrode placement
Electrode placement is important. It is worth the new laryngograph user spending a a while trying out electrode placement, while viewing the waveform live on screen to achieve the largest waveform. It may be an advantage to remove any obstruction to the electrodes e.g. loosen any tie and unbutton the top shirt button. The waveform will be largest when the electrodes are at the level of the vocal folds and the electrical field between the electrodes is most affected by the nature and area of vocal fold contact. For those with a large prominent larynx (typically male) placement is likely to be easy as the wings of the thyroid cartilage are easily found and the acute angle of the larynx will facilitate the concentration of the electrical field in and around the vocal folds. Where the larynx is not prominent (typically female) and particularly when it is covered with a relatively thick layer of fatty tissue it is likely to be harder to find the larynx (the position varies considerably) and more difficult to achieve "good" laryngograph waveforms. For pitch contours even relatively "poor" Lx waveforms should be OK, but comment on the detail of the Lx waveform less certain. The reliability of the waveform can be easily ascertained by inspection of the waveform.

The larynx makes many "gross" adjustments in the course of normal speech e.g. it tends to rise as the voice pitch rises. It is worth watching the response over a range of pitches to ensure optimum placement for the speakers and frequency range you are to study.

For demonstration and experimental purposes it is OK to hold the electrodes in position by hand, but if you are sampling for analysis of range and regularity, it is important to use the neckbands to lightly but firmly secure the electrodes in position because the variation in hand pressure is likely to introduce artifact: a wobble on the waveform due to varying electrode/skin/larynx contact.

Outputs
The speech (Sp) and Laryngograph waveforms (Lx) are accessable from several points on the back of the unit.

A single socket allows one lead to provide the Sp and Lx waveforms for recording, and for playing back.

The "Aux Output" is for linking to the PCLX card in the PC.

3. Making recordings.

Connect from the TAPE IN/OUT socket on the Lx Processor to the LINE IN/OUT socket on the tape recorder.

Switch on the Lx Processor (check the green/amber light)

Connect the microphone and electrodes.

Set the TAPE LIVE switch to LIVE.

The microphone and electrode gain controls have no effect on the Tape output levels so these must be controlled entirely by the line input level controls on the cassette recorder.

Do a test recording to check the levels - Follow the instructions given with the cassette recorder.

See the HINTS and TIPS section of this manual for more details.

4. Playing back recordings

Connect the lead between the Lx Processor TAPE IN/OUT socket and the cassette recorder Line In/Out.

Switch on the Lx Processor

Switch the TAPE LIVE switch to TAPE

Play the recording. The recorded waveforms will now be available from the back panel sockets or routed to the PC.

Waveform polarity
If the waveforms are upside down, this can be corrected by using the small switches marked POLARITY - Lx and Sp.

5. Linking to a PC

Install the PCLX acquistion card in one the vacant slots in the PC as described in the Interface section of this manual.

Connect the Lx Processor AUX output socket to the socket on the acquisition card at the back of the computer with the lead provided.

Switch on the Computer and the Lx Processor.

Plug in and position the microphone and electrodes.

Start the program you wish to use (PcWave to view waveforms, PcPitch to view fundamental frequency or pitch contours). Consult "Acquisition" in the Getting started section of this manual.

6. Knobs and switches

Most of the operation will now be controlled from the computer keyboard. What follows is a brief description of the controls on the Lx processor which you will need to set.

Input
Set the INPUT switch to LIVE if you are using the electrodes and microphone, or to TAPE if you are working from recordings of speech and Lx.

Output
Set the OUTPUT switch to Sp if you wish Fx contours and corresponding analyses to be microphone (speech pressure peak) based or to Lx, if you wish the Fx contours and analyses to be electrode (Lx waveform peak) based.

Usually the Lx, or electrode setting will be best: it measures it measures vocal fold action directly and it is not subject to interference from acoustically noisy environments.

The fundamental frequency programs are based on the measurement of the interval between pulses supplied to a particular input of the PCLX card. Measuring the period in this way enables a resolution of a few microseconds; if the waveforms were digitised and the period measured in software the resolution would be restricted to the maximum analogue sample rate, at best 25 microseconds resolution. The period marking pulses are derived inside the Laryngograph Processor and available on the back panel. One of the connections on the AUX output which connects to the PCLX card has a period marking pulse which is derived from either the speech or the laryngograph waveform according to the position of the front panel OUTPUT switch "Sp" or "Lx". This same pulse is also available from the SWITCHED PULSE socket and the waveform from which it is derived is available on the SWITCHED WAVEFORM socket. Connecting the supplied lead between the AUX socket on the LX Processor and the PCLX card supplies the period marking (Tx) pulses to the PC,

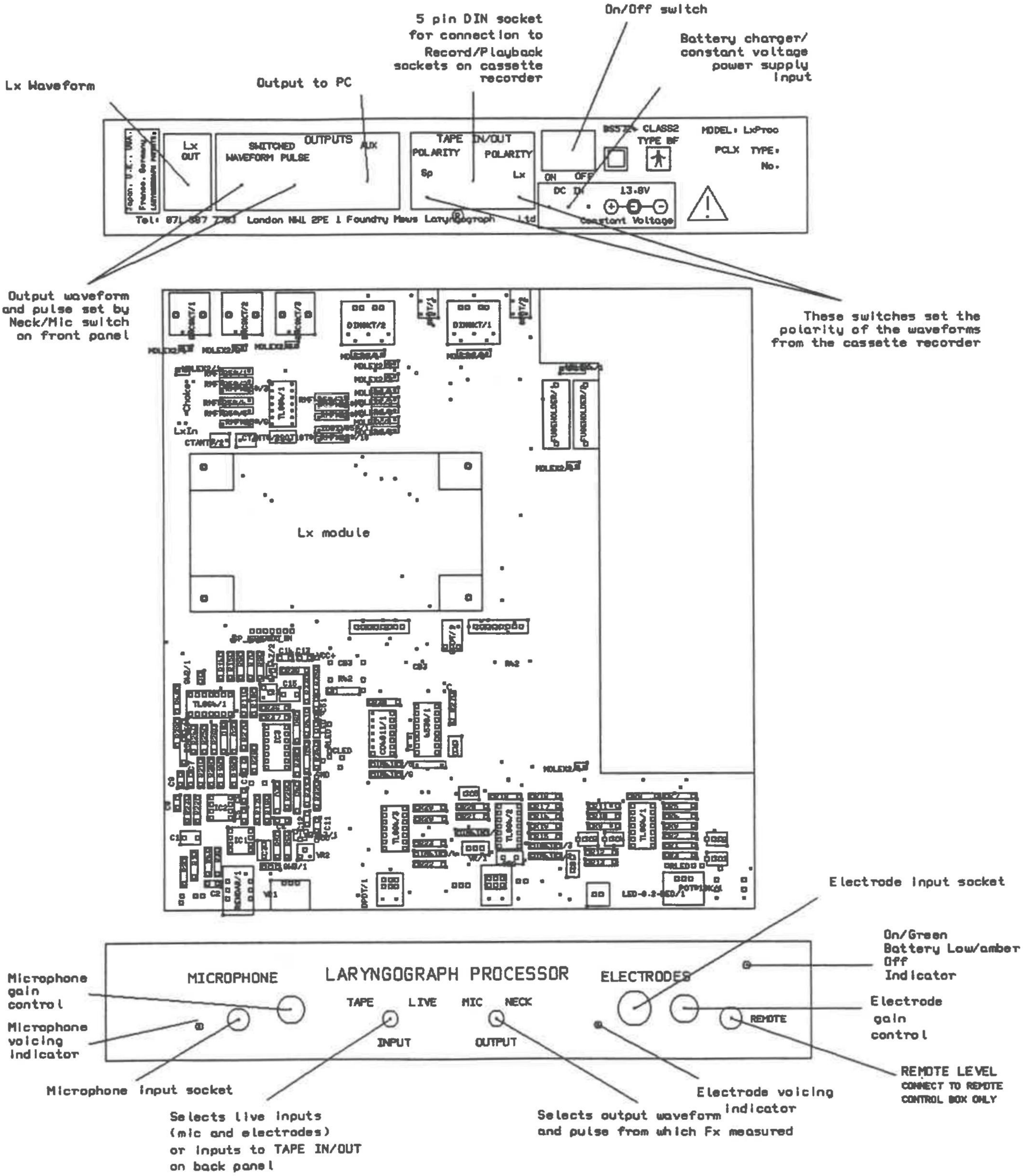
Gain (Volume) controls
Set the gain on the microphone (blue knob) and electrodes (green knob). For the waveform displays this should be fairly obvious - you will see the waveforms on the screen and will just need to check that they are large enough without the tops or bottoms being flattened.

For the Fx and Dx programs you will see the Fx contour in real time and here you need to check that what you see on screen matches your auditory judgement. For example: that high and low notes appear on screen when uttered; that loud and soft voicing appear; that smooth voicing appears as a smooth line; that creak, and rough voice as irregular lines.

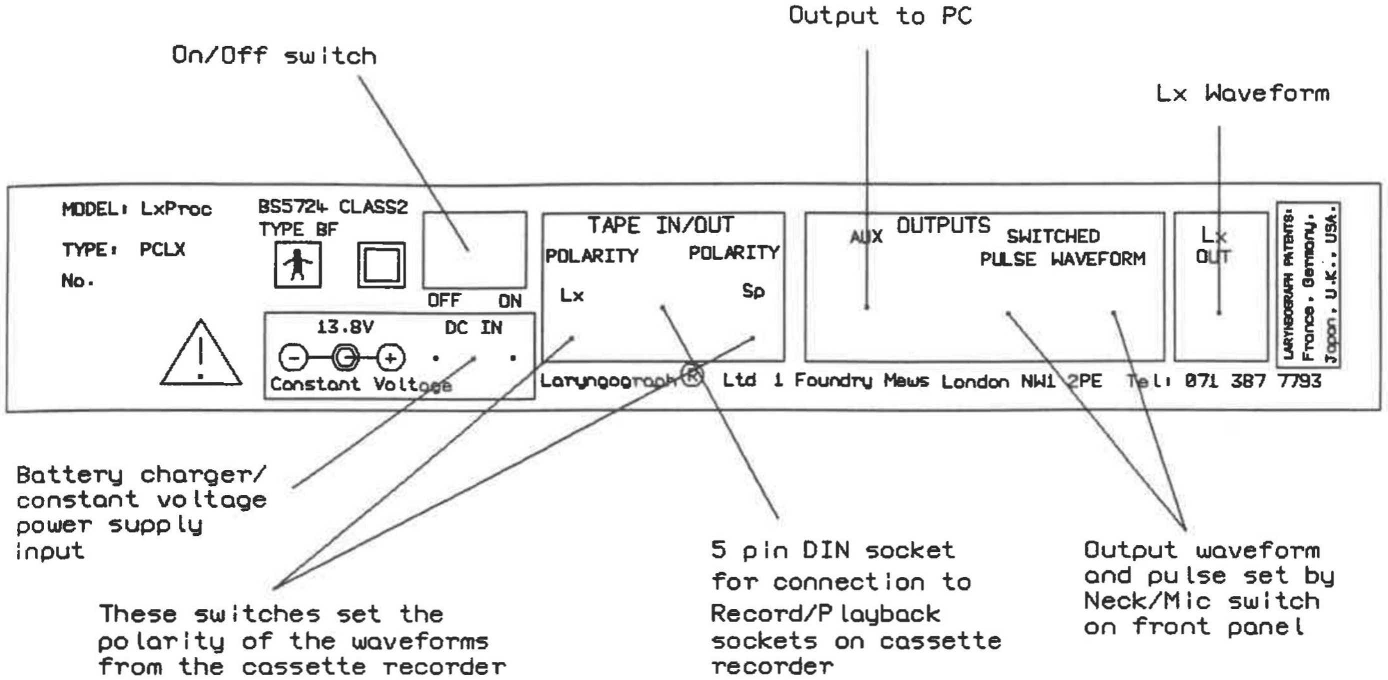
The follow pages give some examples of good and bad gain settings.

Technical Guide

Overall layout


5 pin DIN socket for connection to Record/Playback sockets on cassette recorder
On/Off switch
Battery charger/ constant voltage power supply input
Lx Waveform
Output to PC
Japan, U.K., USA, France, Germany
Lx OUT
SWITCHED WAVEFORM PULSE
OUTPUTS
AUX
TAPE IN/OUT
POLARITY Sp
POLARITY Lx
ON OFF
BS5724 CLASS2 TYPE BF
MODEL: LxProc
PCLX TYPE:
No.
DC IN 13.8V
Constant Voltage
Tel: 071 387 7763 London NW1 2PE 1 Foundry Mews Laryngograph Ltd
Output waveform and pulse set by Neck/Mic switch on front panel
These switches set the polarity of the waveforms from the cassette recorder
Lx module
LxIn
Choke
Electrode input socket
MICROPHONE
LARYNGOGRAPH PROCESSOR
ELECTRODES
TAPE
LIVE
MIC
NECK
INPUT
OUTPUT
REMOTE
Microphone gain control
Microphone voicing indicator
Microphone input socket
Selects live inputs (mic and electrodes) or inputs to TAPE IN/OUT on back panel
Selects output waveform and pulse from which Fx measured
Electrode voicing indicator
On/Green Battery Low/amber Off Indicator
Electrode gain control
REMOTE LEVEL
CONNECT TO REMOTE CONTROL BOX ONLY

Laryngograph Processor (PCLX) - Back panel Ver 2.00


MODEL: LxProc
TYPE: PCLX
No.
BS5724 CLASS2
TYPE BF
OFF ON
13.8V DC IN
Constant Voltage
TAPE IN/OUT
POLARITY Lx
POLARITY Sp
AUX
OUTPUTS
SWITCHED PULSE WAVEFORM
Lx OUT
LARYNGOGRAPH PATENTS: France, Germany, Japan, U.K., USA.
Laryngograph® Ltd 1 Foundry Mews London NW1 2PE Tel: 071 387 7793

On/Off switch

Output to PC

Lx Waveform

Battery charger/
constant voltage
power supply
input

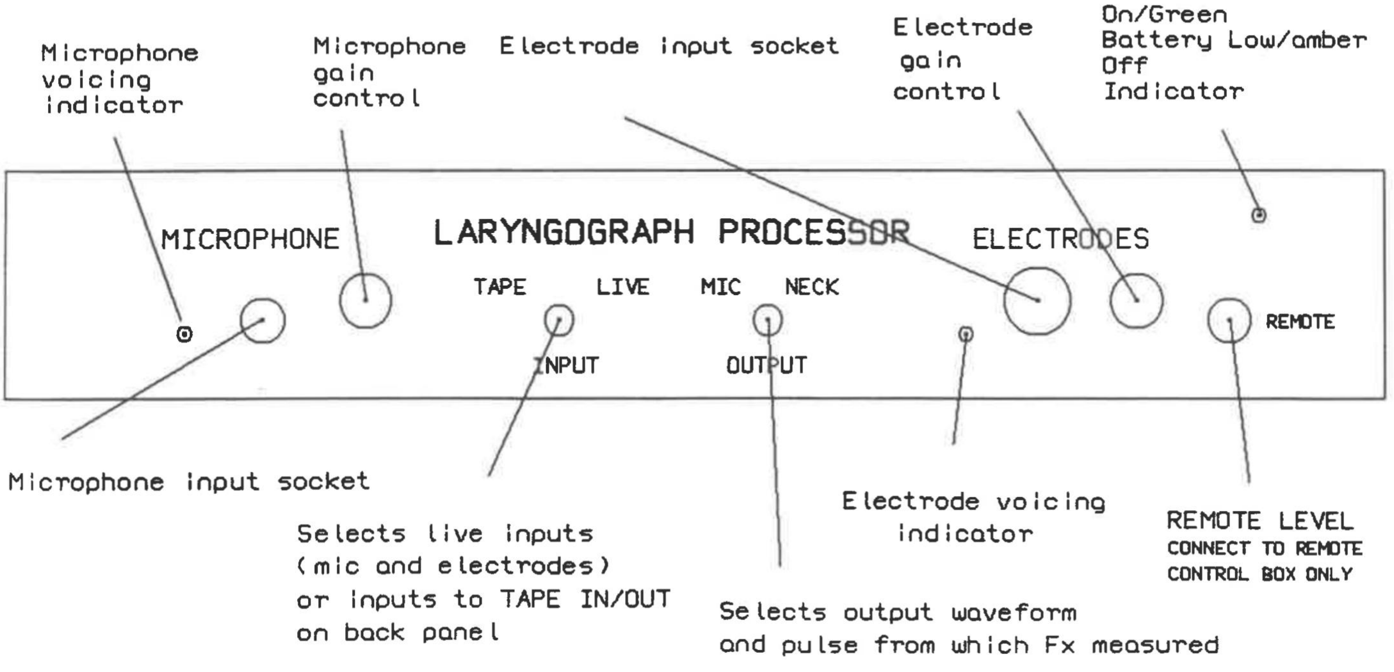
These switches set the
polarity of the waveforms
from the cassette recorder

5 pin DIN socket
for connection to
Record/Playback
sockets on cassette
recorder

Output waveform
and pulse set by
Neck/Mic switch
on front panel

Lx Processor (PCLX)

Front Panel


MICROPHONE
LARYNGOGRAPH PROCESSOR
ELECTRODES
TAPE
LIVE
MIC
NECK
INPUT
OUTPUT
REMOTE

Microphone
voicing
indicator

Microphone
gain
control

Electrode input socket

Electrode
gain
control

On/Green
Battery Low/amber
Off
Indicator

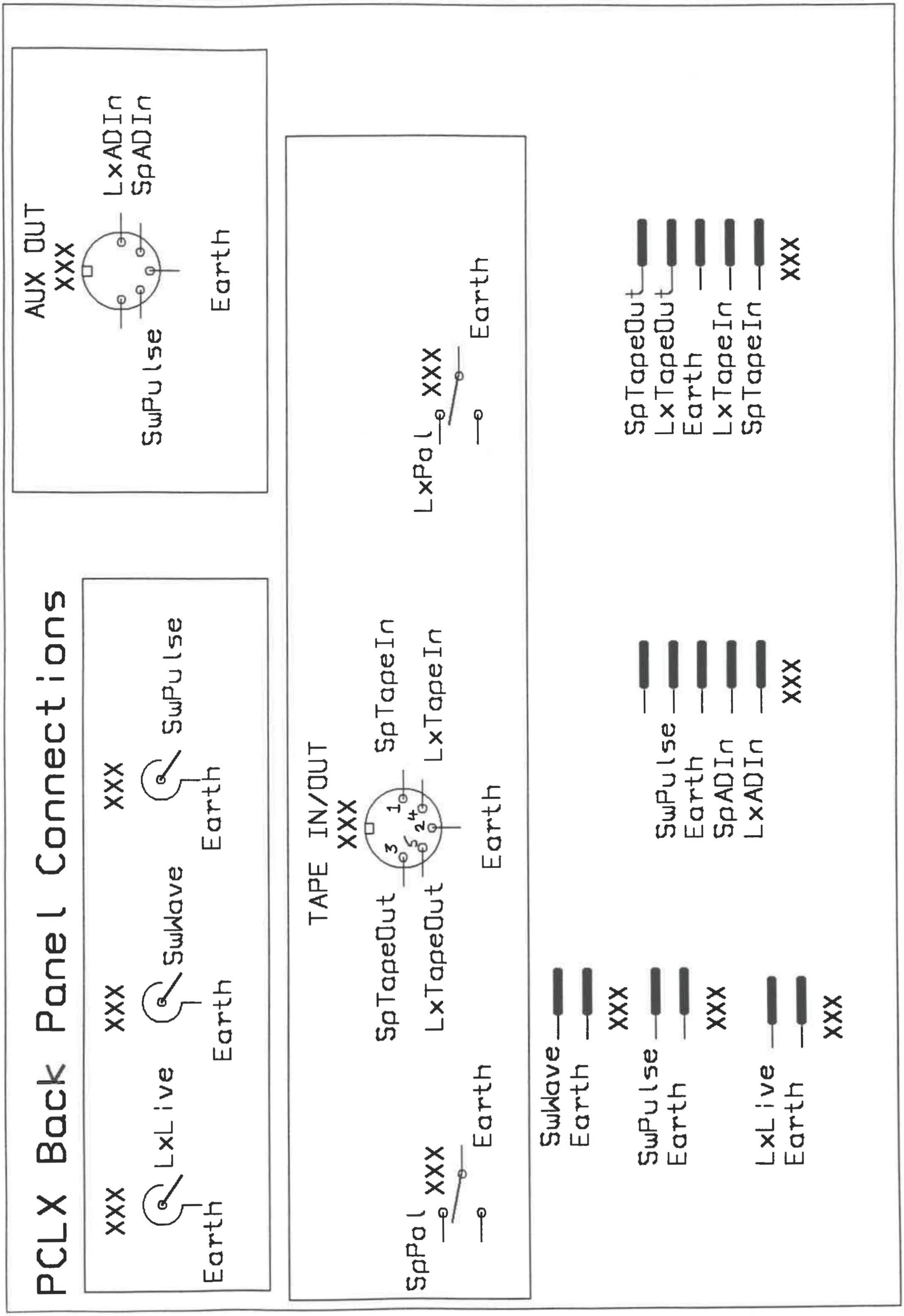
Microphone input socket

Selects live inputs
(mic and electrodes)
or inputs to TAPE IN/OUT
on back panel

Electrode voicing
indicator

REMOTE LEVEL
CONNECT TO REMOTE
CONTROL BOX ONLY

Selects output waveform
and pulse from which Fx measured


PCLX Back Panel Connections
XXX
LxLive
Earth
XXX
SwWave
Earth
XXX
SwPulse
Earth
AUX OUT
XXX
LxADIn
SpADIn
SwPulse
Earth
TAPE IN/OUT
XXX
SpTapeIn
LxTapeIn
SpTapeOut
LxTapeOut
Earth
1
2
3
4
5
SpPol
XXX
Earth
LxPol
XXX
Earth
SwWave
Earth
XXX
SwPulse
Earth
XXX
LxLive
Earth
XXX
SwPulse
Earth
SpADIn
LxADIn
XXX
SpTapeOut
LxTapeOut
Earth
LxTapeIn
SpTapeIn
XXX

Lx Processor Tape recorder connections

The TAPE IN/OUT DIN socket on the back panel of the Lx Processor is wired in the same way as standard cassette reorder IN/OUT sockets.

Pin 3	Left output
Pin 5	Right output
Pin 1	Left Input
Pin 4	Right Input
Pin 2	Earth

To make a connection from DIN socket to DIN socket it therefore necessary to have a lead which has mirror image connections, so that the output of one device goes to the input of the other e.g. RS 478-605.

Alternatively a DIN to four way phono connector can be used.
The following are the colour coded connections for Farnell lead part number 147-706.

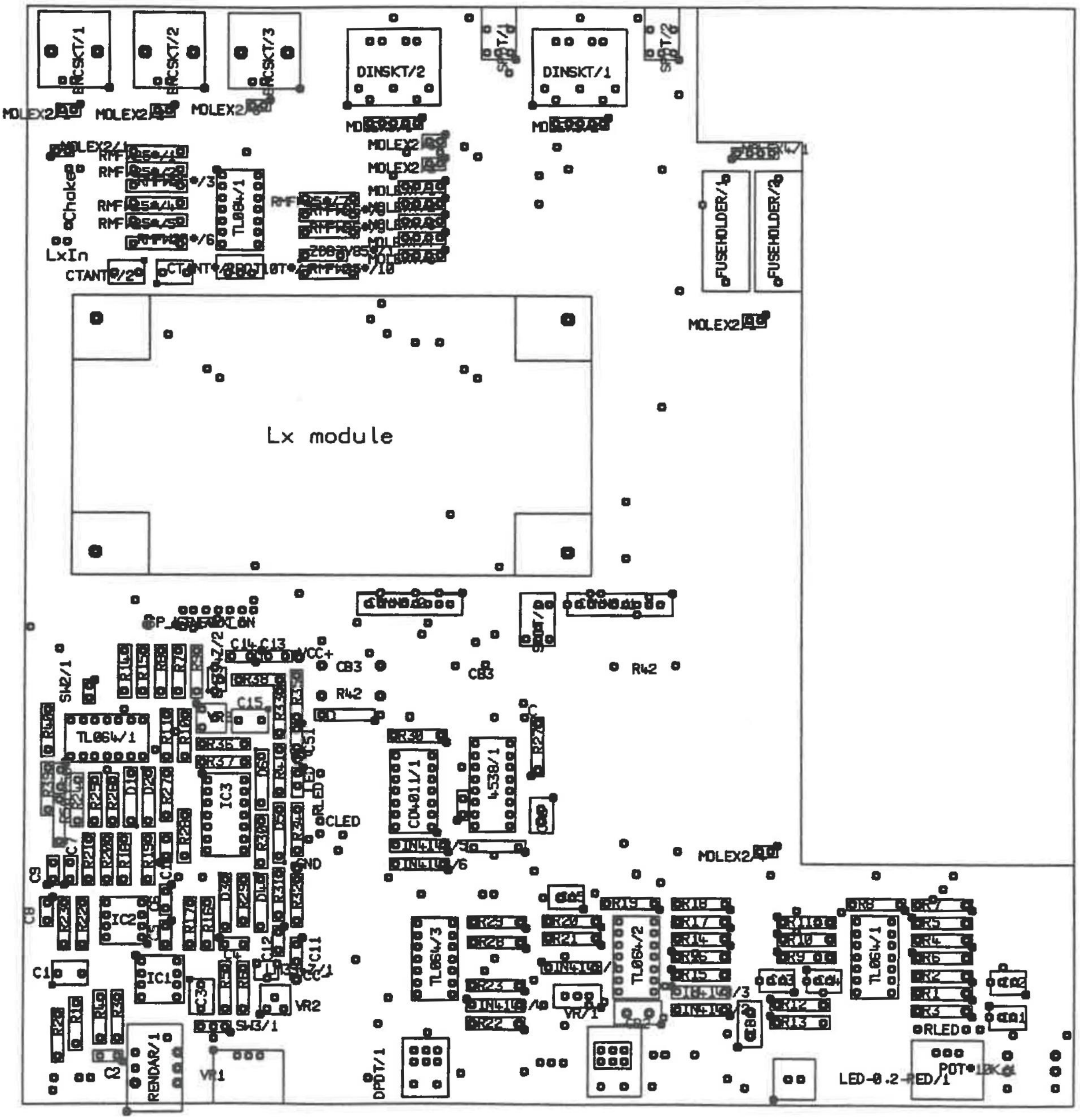
	In	Out
Left (Speech)	Yellow (Pin 1)	White (Pin 3)
Right (Lx)	Blue (Pin 4)	Red (Pin 5)

The Farnell lead 150-847 is colour coded as follows;

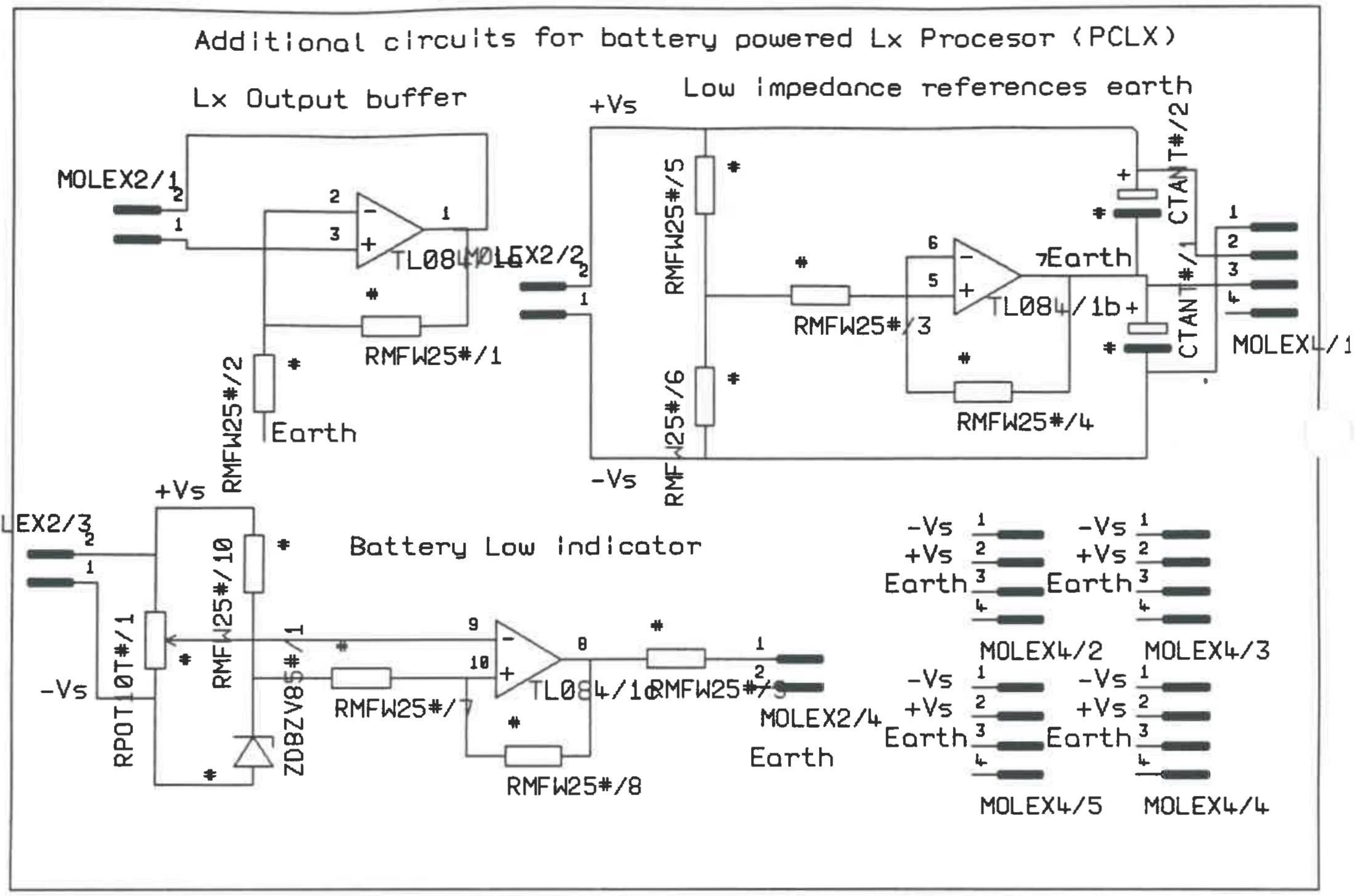
	In	Out
Left (Speech)	Red (pin 1)	Black (pin 3)
Right (Lx)	Yellow (pin 4)	White (Pin 5)

Board layout

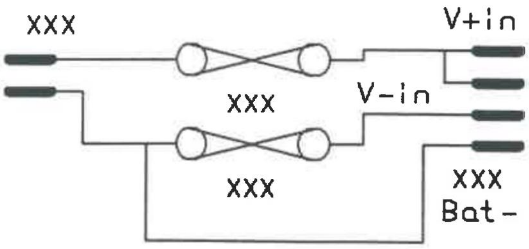
```
PCLXP5.BRD 18Oct1990 20:14 (7) R0 C ...MAIN\HPLASERP.PXY Q1 P15 A  7.50
```


BRCSKT/1
BRCSKT/2
BRCSKT/3
DINSKT/2
DINSKT/1
MOLEX2
Choke
LxIn
CTANT
RMF
TL084/1
FUSEHOLDER/1
FUSEHOLDER/2
Lx module
SW2/1
TL064/1
IC1
IC2
IC3
C14 C13
C15
VCC+
CB3
R42
CD4011/1
4538/1
CLED
RLED
GND
TL064/3
TL064/2
TL064/1
VR/1
VR2
SW3/1
RENDAR/1
VR1
DPDT/1
C1
C2
RLED
POT*10K/1
LED-0.2-RED/1

Miscellaneous - circuits

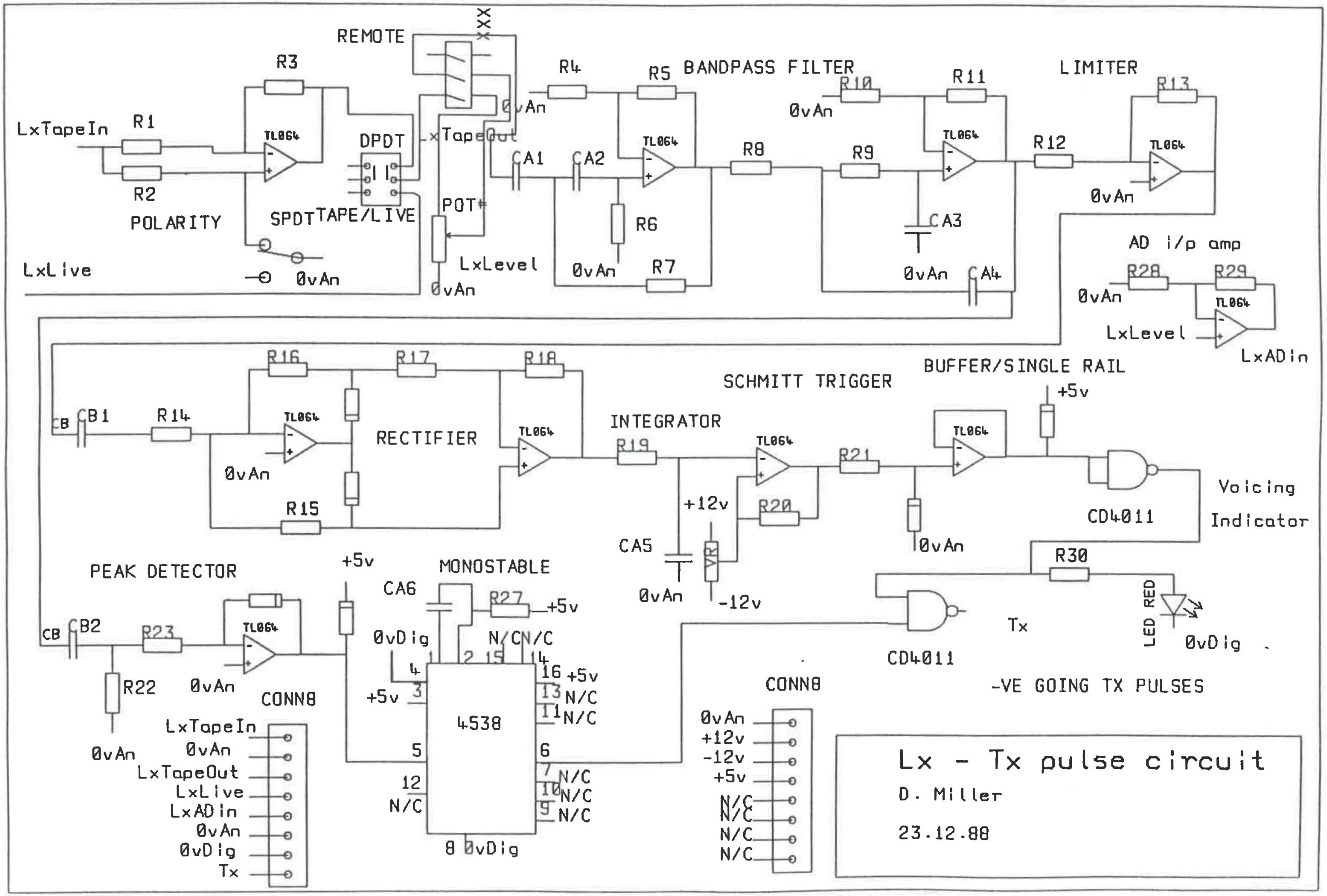

Additional circuits for battery powered Lx Procesor (PCLX)
Lx Output buffer
MOLEX2/1
TL084/1a
RMFW25*/1
RMFW25*/2
Earth
Low impedance references earth
+Vs
-Vs
MOLEX2/2
RMFW25*/5
RMFW25*/6
RMFW25*/3
RMFW25*/4
TL084/1b
Earth
CTANT*/2
CTANT*/1
MOLEX4/1
Battery Low indicator
MOLEX2/3
RPOT10T*/1
RMFW25*/10
ZDBZV85*/1
RMFW25*/7
RMFW25*/8
TL084/1c
RMFW25*/9
MOLEX2/4
Earth
-Vs
+Vs
Earth
MOLEX4/2
MOLEX4/3
MOLEX4/5
MOLEX4/4

Input fusing circuit


XXX
V+in
XXX
V-in
XXX
XXX
Bat-

Miscellaneous - parts
Lx output buffer
Low Impedance reference for battery split supply
Battery low indicator

R1	10K
R2	10K
R3	1K
R4	100K
R5	100K
R6	100K
R7	330R
R8	100K
R9	270R
R10	10K
PRESET	2OK
C1	22UF
C2	22UF
ZD1	2V7
1C1	TL084
	2 x 22UF extra decoupling caps
	1 x protective diode in series from +ve of socket
FUSES	2 x 500mA/t

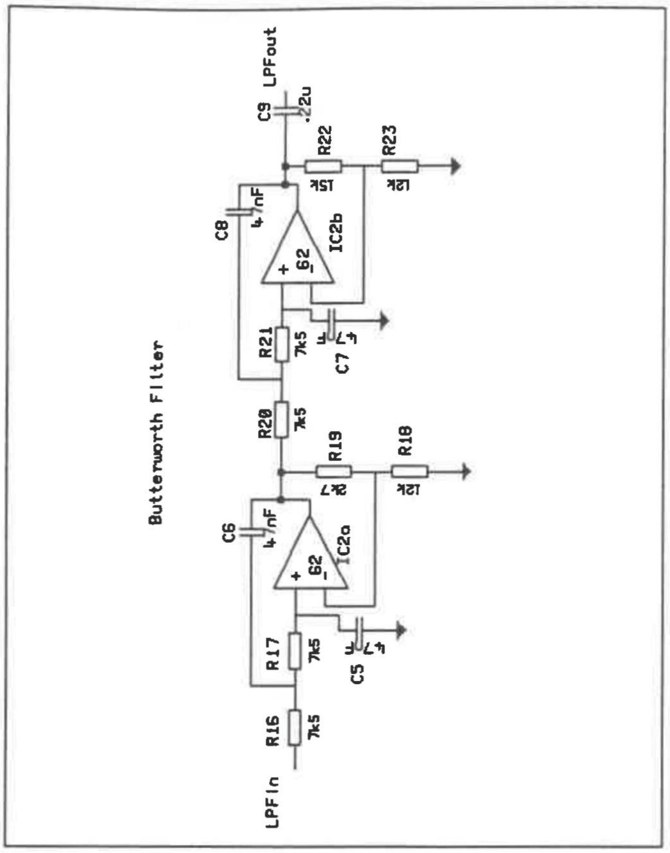

LxTapeIn
R1
R2
POLARITY
R3
TL064
DPDT
SPDT TAPE/LIVE
REMOTE
XXX
LxTapeOut
0vAn
POT#
LxLevel
0vAn
LxLive
0vAn
R4
R5
BANDPASS FILTER
CA1
CA2
TL064
R6
0vAn
R7
R8
R9
R10
0vAn
R11
TL064
CA3
0vAn
CA4
LIMITER
R12
R13
TL064
0vAn
AD i/p amp
R28
R29
0vAn
TL064
LxLevel
LxADin
CB
CB1
R14
R16
R17
R18
TL064
0vAn
RECTIFIER
R15
TL064
INTEGRATOR
R19
+12v
CA5
0vAn
-12v
SCHMITT TRIGGER
TL064
R20
R21
0vAn
BUFFER/SINGLE RAIL
+5v
TL064
CD4011
Voicing Indicator
R30
LED RED
0vDig
CD4011
Tx
-VE GOING TX PULSES
PEAK DETECTOR
CB
CB2
R23
R22
0vAn
TL064
0vAn
+5v
MONOSTABLE
CA6
R27
+5v
0vDig
N/C
N/C
4538
1
2
15
14
4
3
+5v
16 +5v
13 N/C
11 N/C
5
6
12 N/C
7 N/C
10 N/C
9 N/C
8 0vDig
CONN8
LxTapeIn
0vAn
LxTapeOut
LxLive
LxADin
0vAn
0vDig
Tx
CONN8
0vAn
+12v
-12v
+5v
N/C
N/C
N/C
N/C
Lx - Tx pulse circuit
D. Miller
23.12.88

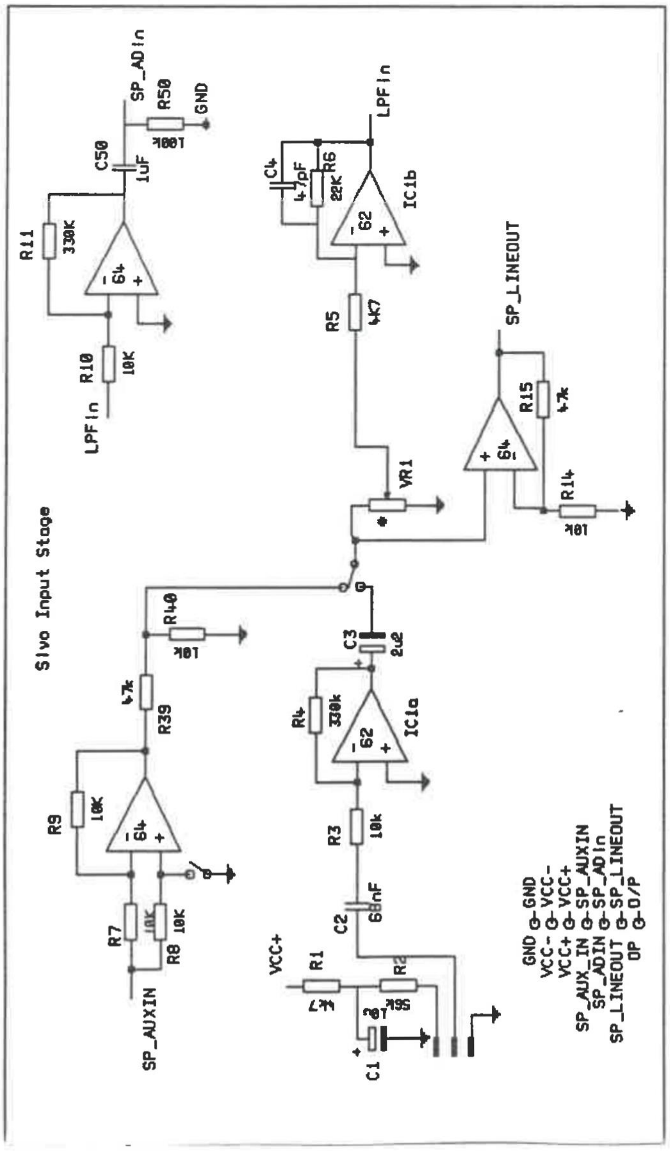
Tx - Parts

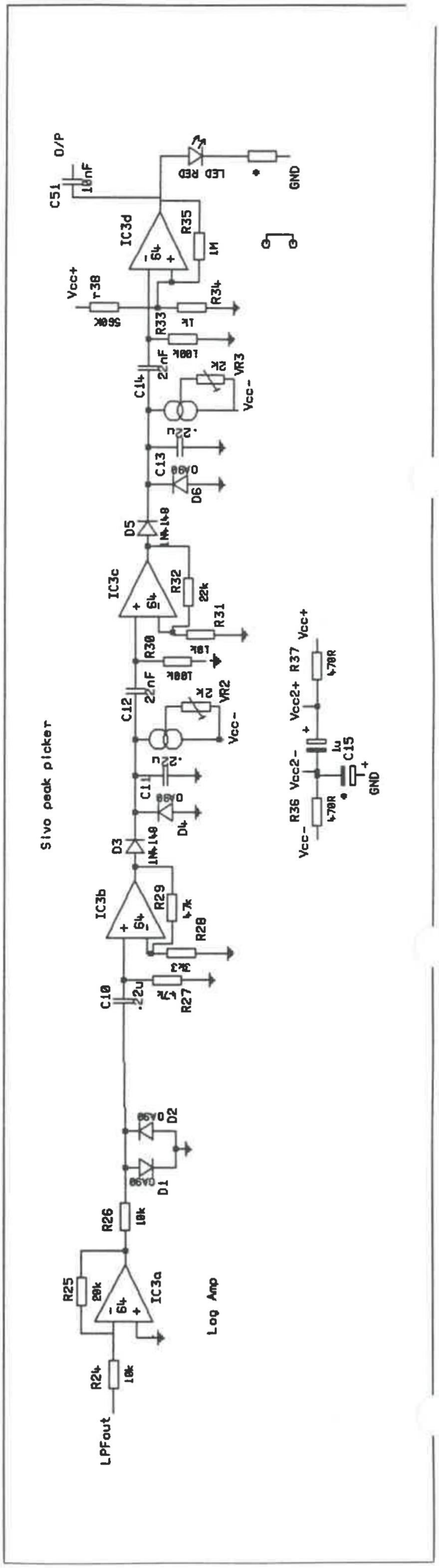
I.C.'s		Capacitors	
IC1,2,3	TLO64	CA1	15nF
IC4	4538	CA2	15nF
IC5	4011	CA3	15nF
		CA4	15nF
Diodes		CA5	68nF
D1-4	1N4148	CA6	1nF
LED	Green	CB1	2u2
		CB2	2u2

Resistors			
R1	10K	R16	22K
R2	10K	R17	22K
R3	10K	R18	22K
R4	39K	R19	100K
R5	10K	R20	330K
R6	390K	R21	1M
R7	390K	R22	10K
R8	2K7	R23	820R
R9	2K7	R24	
R10	39K	R25	
R11	10K	R26	
R12	33K	R27	1M
R13	1M5	R28	20K
R14	22K	R29	220K
R15	22K	R30	4K7

VR1	20K
Gain pot	10K


Butterworth Filter
LPFin
R16 7k5
R17 7k5
C5 47u
C6 47nF
IC2a
R19 2k7
R18 12k
R20 7k5
R21 7k5
C7 47u
C8 47nF
IC2b
R22 15k
R23 12k
C9 .22u
LPFout

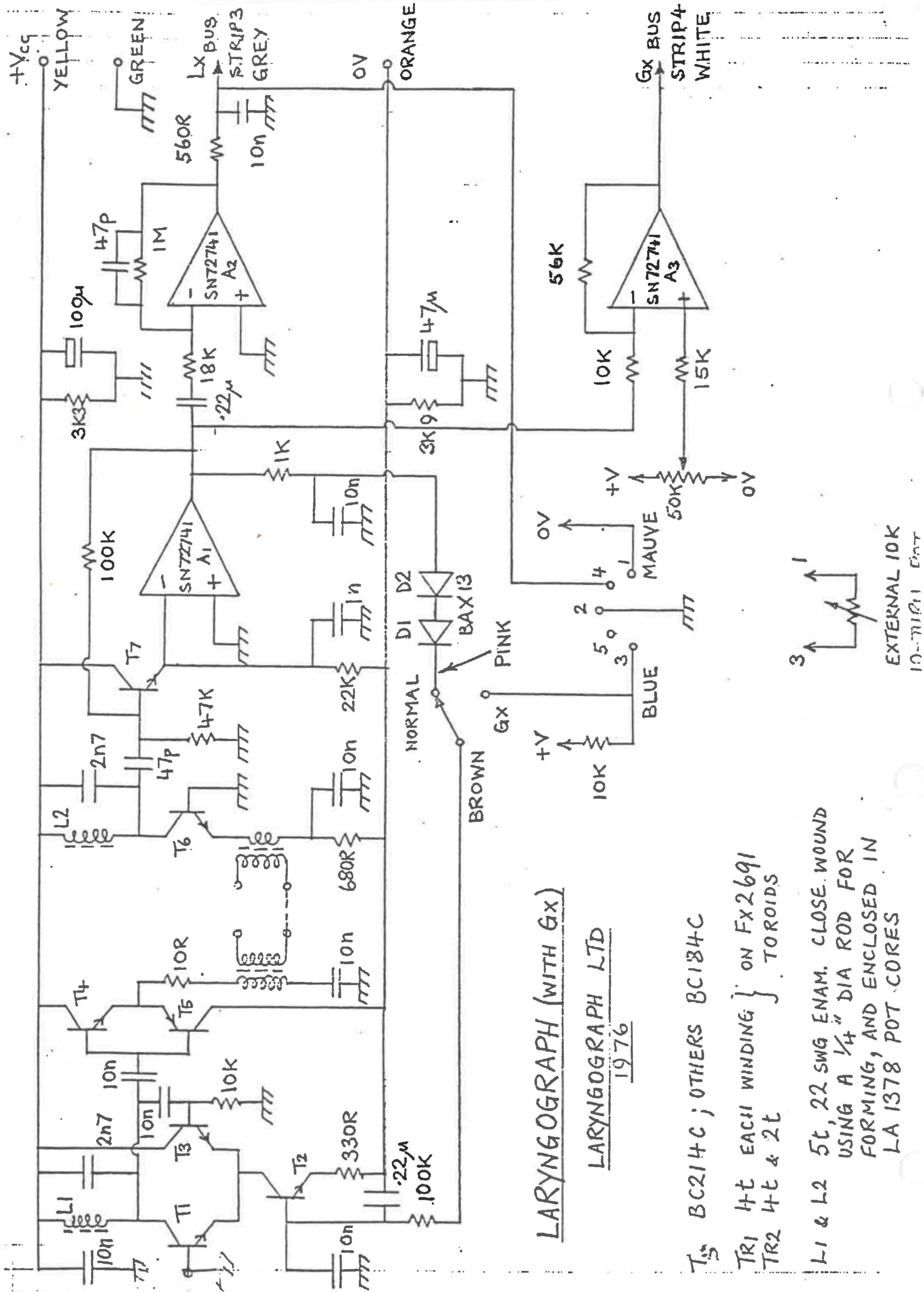

Sivo Input Stage
SP_AUXIN
R7 10K
R8 10K
R9 10K
R39 47k
R40 10K
VCC+
R1 4k7
R2 56k
C1 10u
C2 68nF
R3 10k
R4 330k
IC1a
C3 2u2
VR1
R5 4K7
R6 22K
C4 47pF
IC1b
LPFin
R14 10K
R15 47k
SP_LINEOUT
LPFin
R10 10K
R11 330K
C50 1uF
R50 100K
SP_ADin
GND
GND G-GND
VCC- G-VCC-
VCC+ G-VCC+
SP_AUX_IN G-SP_AUXIN
SP_ADIN G-SP_ADIn
SP_LINEOUT G-SP_LINEOUT
OP G-O/P


Sivo peak picker
Log Amp
LPFout
R24 10k
R25 20k
IC3a
R26 10k
D1 OA90
D2 OA90
C10 .22u
R27 4k7
R28 3k3
R29 47k
IC3b
D3 1N4148
D4 OA90
C11 .22u
VR2 2k
Vcc-
C12 22nF
R30 100K
R31 10K
R32 22k
IC3c
D5 1N4148
D6 OA90
C13 .22u
VR3 2k
Vcc-
C14 22nF
R33 100K
R34 1k
r38 560K
Vcc+
IC3d
R35 1M
C51 10nF
O/P
LED RED
GND
Vcc- R36 470R Vcc2-
C15 1u
GND
Vcc2+ R37 470R Vcc+

Mic Fx - parts

Semiconductors		Capacitors	
IC1	TL062	C1	10uF
IC2	TL062	C2	68nF
IC3	TL064	C3	2u2
IC4	TL064	C4	47pF
Current source	LM334	C5	47nF
D1	OA90	C6	47nF
D2	OA90	C7	47nF
D3	1N4148	C8	47nF
D4	OA90	C9	.22uF
D5	IN4148	C10	.22uF
D6	0A90	C11	.22uF
		C12	22nF
VR1	10K Log	C13	.22uF
VR2	2K	C14	22nF
VR3	2K	C15	1uF
		C50	1uF
		C51	10nF
		C52	47uF

Resistors			
R1	4K7	R22	15K
R2	56K	R23	12K
R3	10K	R24	10K
R4	330K	R25	20K
R5	4K7	R26	10K
R6	22K	R27	47K
R7	10K	R28	3K3
R8	10K	R29	47K
R9	10K	R30	100K
R10	10K	R31	10K
R11	100K	R32	22K
R12		R33	100K
R13		R34	1K
R14	10K	R35	1M
R15	47K	R36	470R
R16	7K5	R37	470R
R17	7K5	R38	560R
R18	12K	R39	LINK
R19	2K7	R40	
R20	7K5	R41	2K2
R21	7K5	R50	100K


+Vcc
YELLOW
GREEN
Lx BUS
STRIP3
GREY
0V
ORANGE
Gx BUS
STRIP4
WHITE
560R
10n
47p
1M
SN72741
A2
100μ
18K
3K3
·22μ
47μ
3K9
56K
SN72741
A3
10K
15K
1K
10n
+V
50K
0V
0V
MAUVE
4
1
2
5
3
100K
SN72741
A1
T7
1n
D1
D2
BAX13
PINK
22K
47K
NORMAL
Gx
BLUE
2n7
47p
10n
+V
10K
BROWN
L2
T6
680R
10R
10n
T4
T5
10n
10K
2n7
10n
T3
T2
330R
·22μ
100K
L1
T1
10n
10n
1
3
EXTERNAL 10K

LARYNGOGRAPH (WITH Gx)

LARYNGOGRAPH LTD
1976

T5 BC214C ; OTHERS BC184C

TR1 4t EACH WINDING } ON Fx2691
TR2 4t & 2t } TOROIDS

L1 & L2 5t, 22 SWG ENAM. CLOSE WOUND USING A 1/4" DIA ROD FOR FORMING, AND ENCLOSED IN LA 1378 POT CORES

INSTANTANEOUS VOICE PERIOD MEASUREMENT FOR COCHLEAR STIMULATION

Indexing terms: Signal processing, Speech processing

A peak-picking method for measuring the instantaneous period of voiced speech is described and compared with three other well documented techniques. It has been developed for use with a cochlear prosthesis to provide electrically stimulated hearing in a number of totally deaf adults. In this way both receptive and productive abilities can be substantially improved.

During normal voiced speech the vocal folds vibrate between open and closed phases fairly regularly, with each closure initiating an acoustic pressure pulse as input to the vocal tract. The frequency of vocal fold vibration gives a direct measure of speech fundamental frequency which is subjectively realised as the pitch of the voice.

The basis for understanding voice pitch perception has traditionally been provided by two main theories: the place theory and the temporal theory. The most successful contemporary models involve the combination of these two processes, with a primarily temporal analysis preceded by an initial filtering stage.[1]

Solutions to the problem of fundamental frequency measurement have been sought in both the frequency domain[2] and the time domain.[3] For electrocochlear stimulation[4] a device is needed which will respond reliably to changes in fundamental frequency, thereby providing the patients with the pitch patterns of speech—a speech feature of basic importance at both speech sound and intonation levels, but one which is totally invisible to the lipreader.

The patients respond to pitch approximately in the range 50–400 Hz[4] and since peripheral place analysis is not involved their sensation can only be as a result of time-domain processing. This implies that a time-domain device would best suit the patient as a lipreading aid, as it would preserve laryngeal information in synchrony with the speech waveform.

To achieve these aims, we have designed a peak-picking device based on one first implemented by Gruenz and Schott,[5] but with novel features. Its operation depends on the fact that the pressure waveform for voiced speech, when undistorted in phase, has one major peak per period. Fig. 1*a* illustrates this with a typical tape recorded waveform for the vowel [ɑ] as in the word 'card'. The device aims to isolate these major peaks, and to output one pulse for each, thus defining the fundamental period. If the input is voiceless speech or silence, additional preprocessing stages ensure that the peak-picking stages of the device do not receive any peaks of sufficient amplitude to be detected.

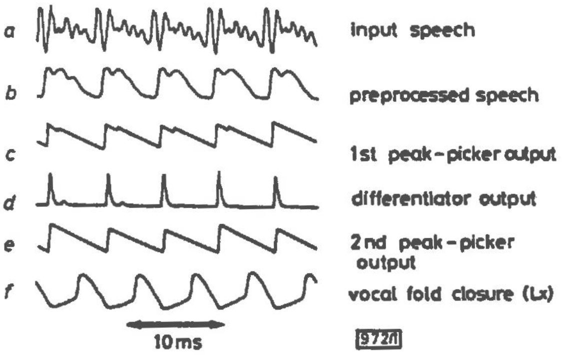


Fig. 1 *Peak-picker and laryngograph waveforms*

The speech input is derived from an electret microphone, which preserves low-frequency phase information. This is then amplified and presented to two preprocessing stages. The first is a 4-pole Butterworth lowpass filter, typically with a cutoff frequency of 450 Hz. For voiced sounds, the output of this filter will normally contain the fundamental component with possibly a few harmonics, but for voiceless sounds, the output will typically be of small amplitude. The second stage is a logarithmic amplifier, which ensures that the rapid overall amplitude variations, common in speech, do not reach the peak-picker itself. Fig. 1*b* shows the preprocessed version of Fig. 1*a*. The first major peak in each cycle must be positive going at this stage to ensure successful operation of the peak-picking stages.

The first peak-picker stage consists of a circuit whose output voltage follows its input voltage only when the input is the greater of the two. The output follows a preset decay rate when the input voltage is below the output voltage, giving the waveform shown at Fig. 1*c*. This waveform will normally itself contain just one peak per period, but occasionally, especially for low-pitch speakers and for vowels with a low first formant frequency, it may contain secondary peaks. These are made less significant by differentiation, which has the effect of reducing their amplitude with respect to the major peaks, as shown at Fig. 1*d*. The peak-picking process is then repeated giving the waveform shown at Fig. 1*e*, which after peak-clipping contains just one pulse per period of the input voiced speech waveform.

Experimentally, this peak-picking processor has been compared with three other real-time devices: a laryngograph;[6] a cepstrum processor;[2] and a hardware version of the Gold–Rabiner algorithm.[3] The laryngograph monitors vocal fold activity directly and is used as a 'standard' against which to compare the other devices. Its output waveform (Lx) for the vowel pressure waveform at Fig. 1*a* is shown in Fig. 1*f*.

Comparison is made using a recording of about two to three minutes of a phonetically balanced read text. The speech pressure waveform from a microphone and the Lx waveform are recorded simultaneously on the two channels of a stereo tape recorder. The output of each device is analysed so as to produce a fundamental frequency scatter plot, as shown in Fig. 2, with the fundamental frequency value for one period (Fx_2) plotted against the value for the previous period (Fx_1). This gives an indication of both the frequency range and temporal regularity of the fundamental frequency measured.[6]

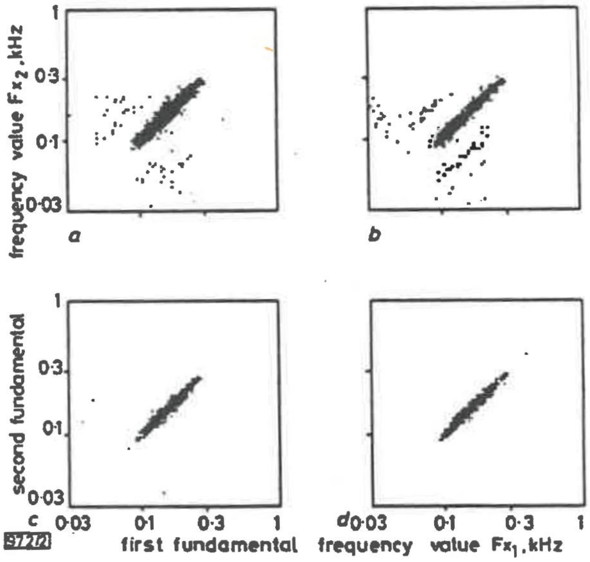


Fig. 2 *Fundamental frequency scatter plots*

a Laryngograph
b Peak-picker
c Gold–Rabiner
d Cepstrum

The length of the diagonal ($Y = X$) line is similar in all four plots, indicating that the range of frequencies responded to by each device is comparable. The scatter of points away from this diagonal line indicates the regularity of fundamental frequency change. Significant scatter is clearly shown at low frequencies for both the laryngograph and the peak-picker. This scatter is due to a creaky voice, a natural effect common in speech, when vocal fold vibration is irregular, a fact easily quantified by examination of the Lx waveform. The Gold–Rabiner and cepstrum devices do not show this effect both because they incorporate output smoothing algorithms, and because they are intrinsically designed not to allow for such irregularities in voiced speech. This smoothing also accounts for the relative narrowness of the diagonal line in their scatter

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plots as compared to the plots obtained from the laryngograph and the peak-picker.

All four devices have also been compared in connected discourse tracking tests with normal listeners. The results[7] showed that the cepstrum device with its inherent processing delay is consistently poor. The other three devices give similar improvement in communication rate over lipreading alone, with the peak-picker possibly being the best.

Use of this peak-picking device with patients[4] has shown that their communication rate is greatly increased when this invisible pitch information is added to the visual information available from lipreading, and also that their own speaking fundamental frequency range and regularity tend towards normal when they are able to monitor their own voice. The device itself is now pocket-sized and battery powered, and provides the basis for a possible implementation as a behind-the-ear aid in the future.

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15th July 1983

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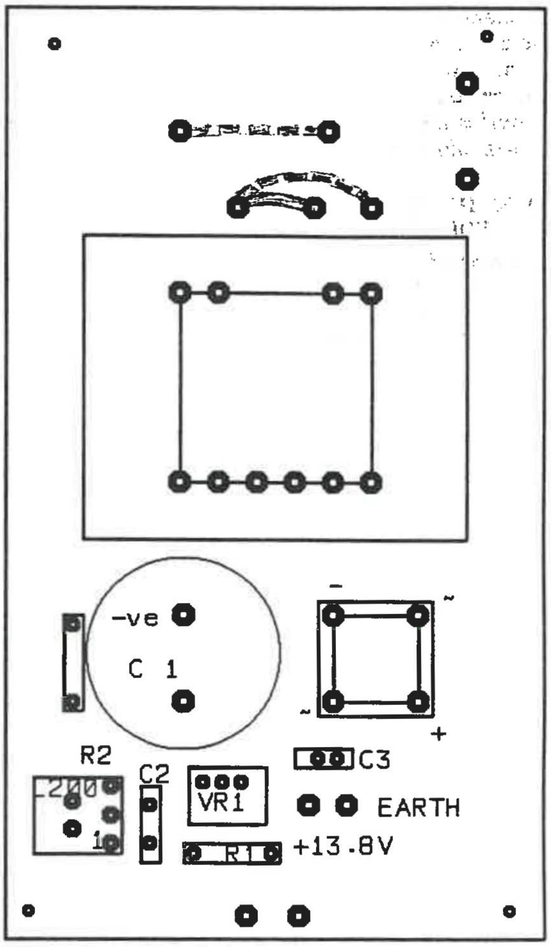
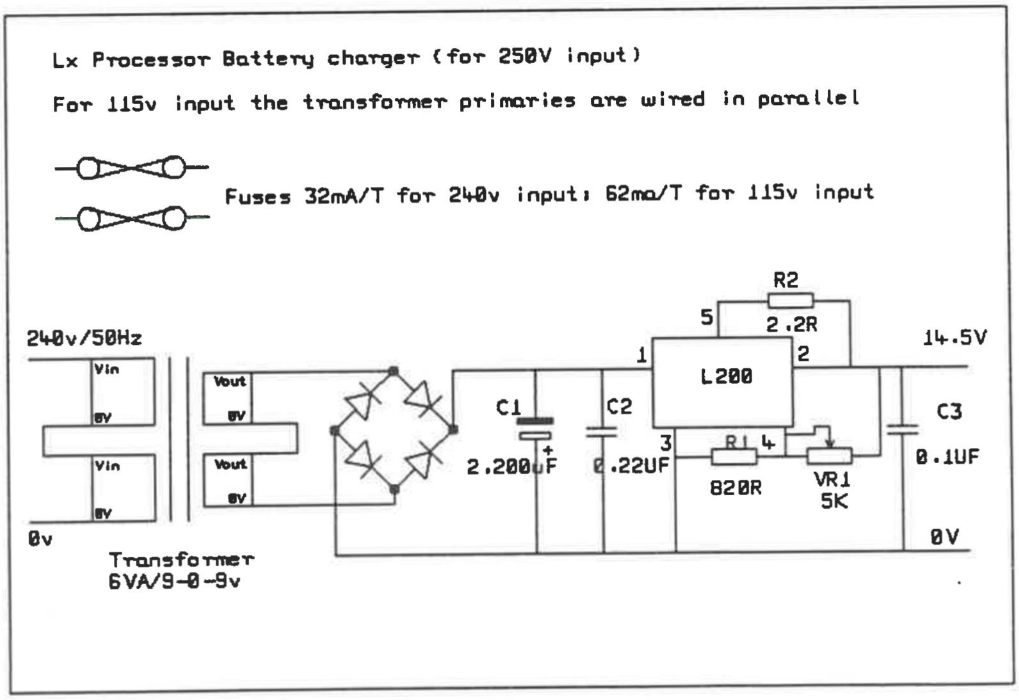
Battery charger board and components

Fuses	240v 32mA/T 115v 63mA/T
Links	Solid = 240v dotted= 115v
R1	820R
R2	2R2
VR1	5K
C1	2,200UF
C2	0.22UF
C3	0.1UF
Transformer	9-0-9 6VA
Diode bridge	
Regulator	L200
Mains switch	
IEC inlet	


-ve
C 1
-
~
~
+
R2
2R0
C2
VR1
C3
EARTH
R1
+13.8V
1


Lx Processor Battery charger (for 250V input)

For 115v input the transformer primaries are wired in parallel

Fuses 32mA/T for 240v input; 62ma/T for 115v input

240v/50Hz
Vin
0V
Vin
0V
0v
Vout
0V
Vout
0V
Transformer
6VA/9-0-9v
C1
2.200uF
+
C2
0.22UF
L200
1
2
3
4
5
R2
2.2R
R1
820R
VR1
5K
14.5V
C3
0.1UF
0V